Are Flood Stages Rising? Our Fault or Mother Nature's?!

AIC Surveyors Affiliate Meeting

September 22, 2015

Presented by:

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Christopher B. Burke Engineering, LLC


“Flooding is now more frequent and more severe!”
“It’s because of that new bridge restricting flow!”
“No, it’s all the impervious area at that new industrial complex!”
“No, it’s just climate change!”

Is Flooding Getting Worse?

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- **What factors go into making a flood?**

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- What factors go into making a flood?
- **What's happening with these factors?**

Is Flooding Getting Worse?

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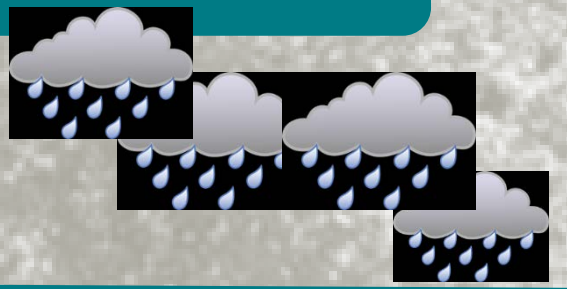
- **What are the implications?**

Is Flooding Getting Worse?

- What factors go into making a flood?
- What's happening with these factors?
- What are the implications?

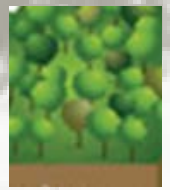
Can We Do Anything?

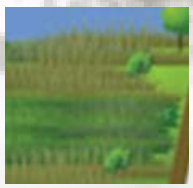
• What factors go into making a flood?



1) Rainfall

2) Surface, soil & slope





3) Flow Path

Best Case Scenario

Worst Case Scenario

Is Flooding Getting Worse?

- What factors go into making a flood?
- **What's happening with these factors?**

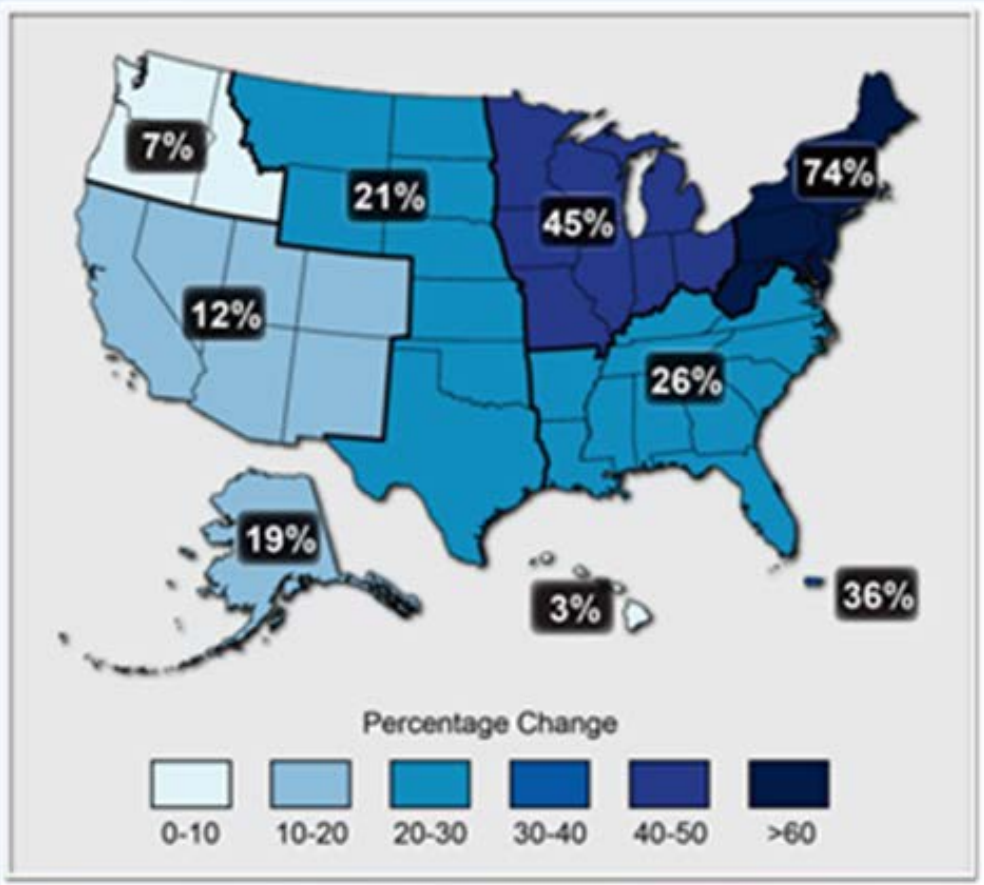
1) Rainfall
2) Land use, soil, slopes
3) Flow path

What's Happening to: 1) Rainfall?

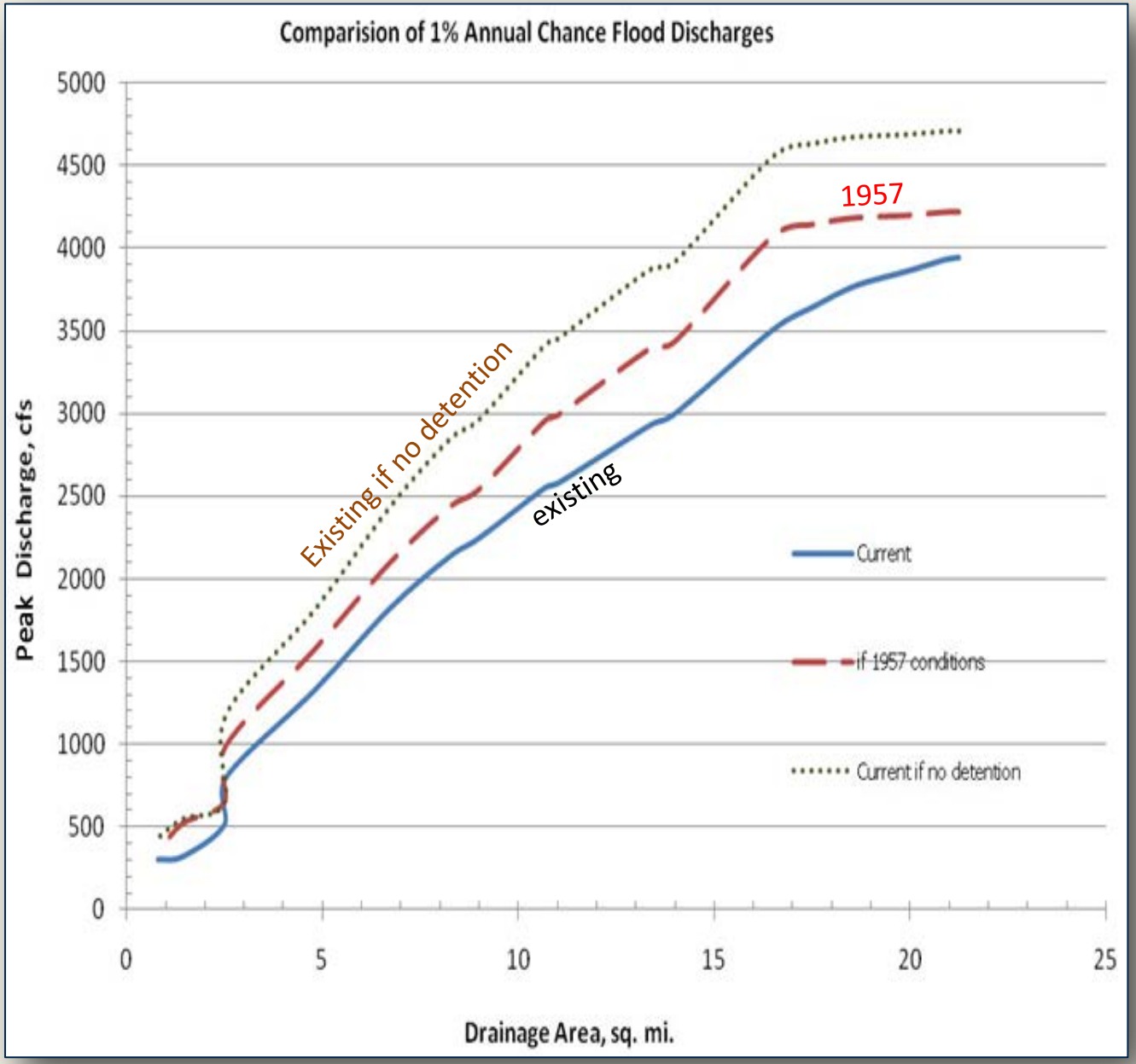
Observed Change in Very Heavy Precipitation

- 1958 to 2011
- "Very Heavy Events" = Heaviest 1% of all daily events
- Clear trends toward a greater amount of very heavy precipitation for the nation as a whole
  - Particularly in the Northeast and Midwest

Melillo et al. 2013 National Climate Assessment
Draft for Public Comment



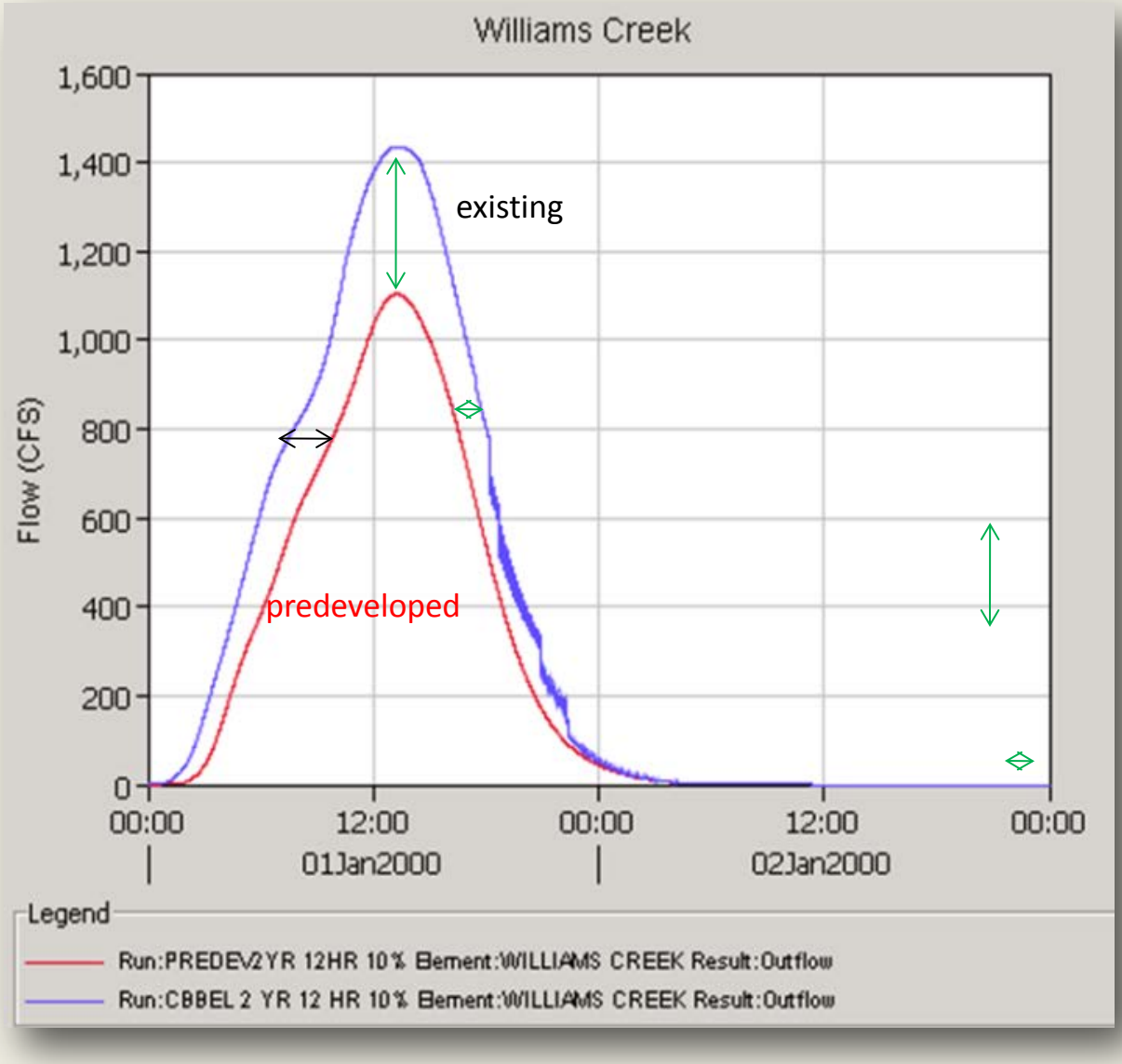
What's Happening: 2) Because of Land Use?
Impacts of Regulated Development – 100 Year Peak Discharge



Release Rate requirements (detention)

Prevent a small range of runoff increases from becoming <u>peak discharge</u> increases

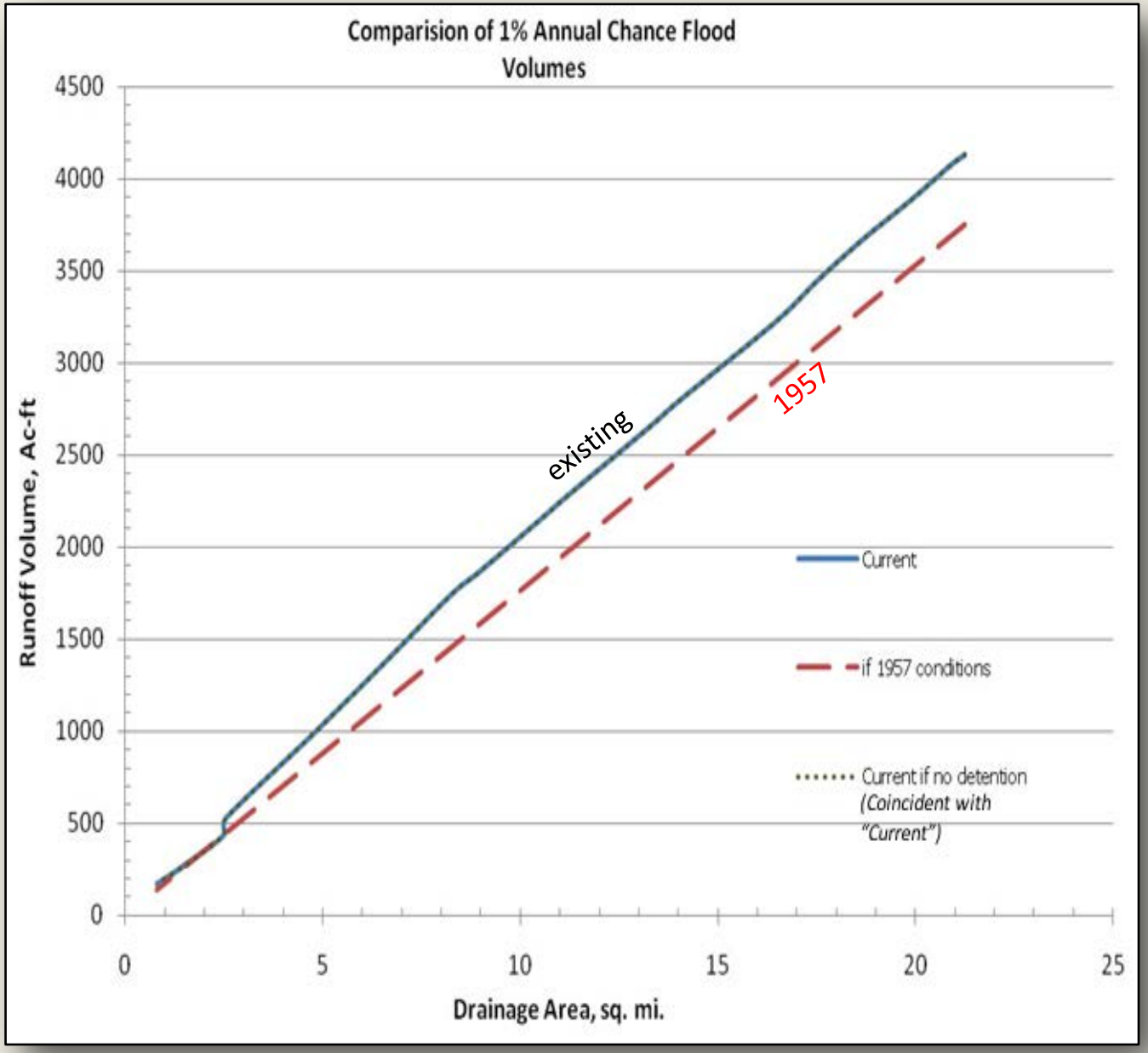
What's Happening: 2) Because of Land Use?
2-year Discharge Increases With Watershed Development When Regulations Only Address Higher Discharges



Impacts?

- flood <u>peak</u>
- <u>bankfull duration</u>
- increased channel erosion observed

What's Happening: 2) Because of Land Use?
Impacts of Development If Only Regulate Discharge Peaks



~10% ⬆ in runoff <u>volume</u> *(not peak discharge)* *f*or 100-yr rainfall

What's Happening: 3) to the Flow Path?

Impact of Allowing Loss of Flood Conveyance and Storage (Fill, Levees, crossings, etc)

- **Regulation of Floodway Only**

  Fill fringe areas (shown in green) as allowed by many community ordinances:

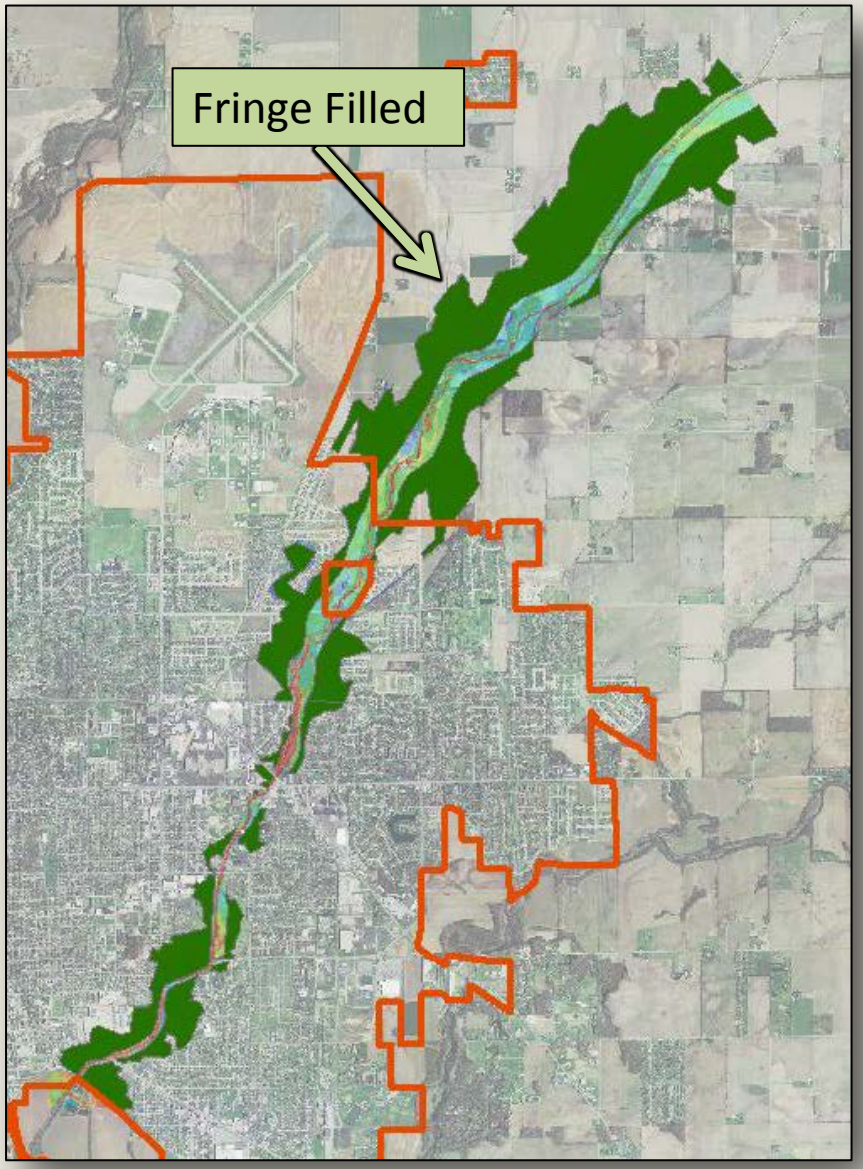
  100-year peak flood elevations
  - **½ - 1 ½ foot increases**

  500-year peak flood elevations
  - **1-5 foot increases**

  Development in the Floodway Fringe:

  - May or may not impact traditional regulatory elevations
  - Will impact observed elevations

- **Levees**
  - Impact on larger than 100-yr flows
- **Crossings**
  - Many are unregulated or are designed only for 100-yr flood
- **Channel Aggradation**
  - Increased Streambank Erosion



What's Happening: 3) to the Flow Path?
What are streams doing with the runoff they receive?

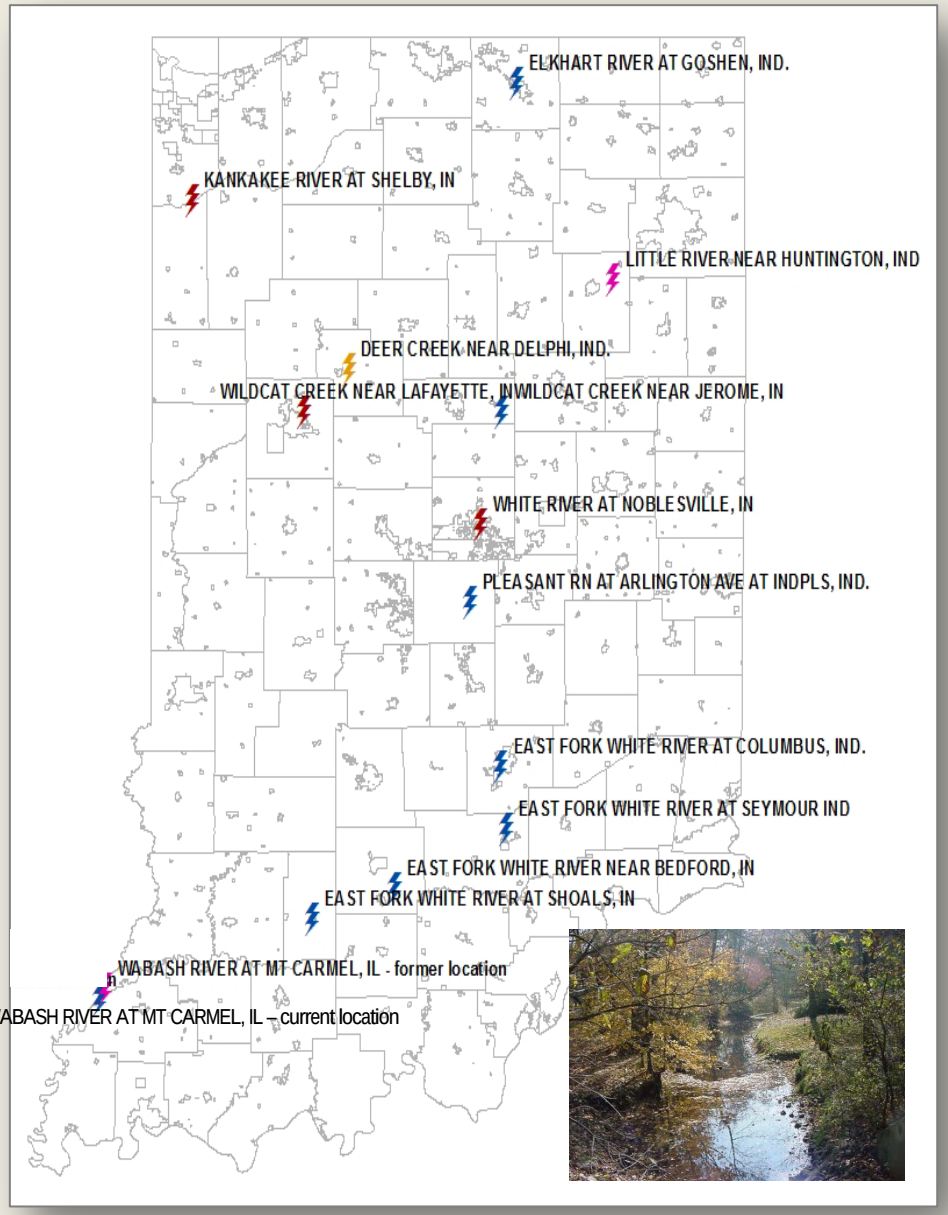
Real Measured Data

USGS Streamflow Gage Data

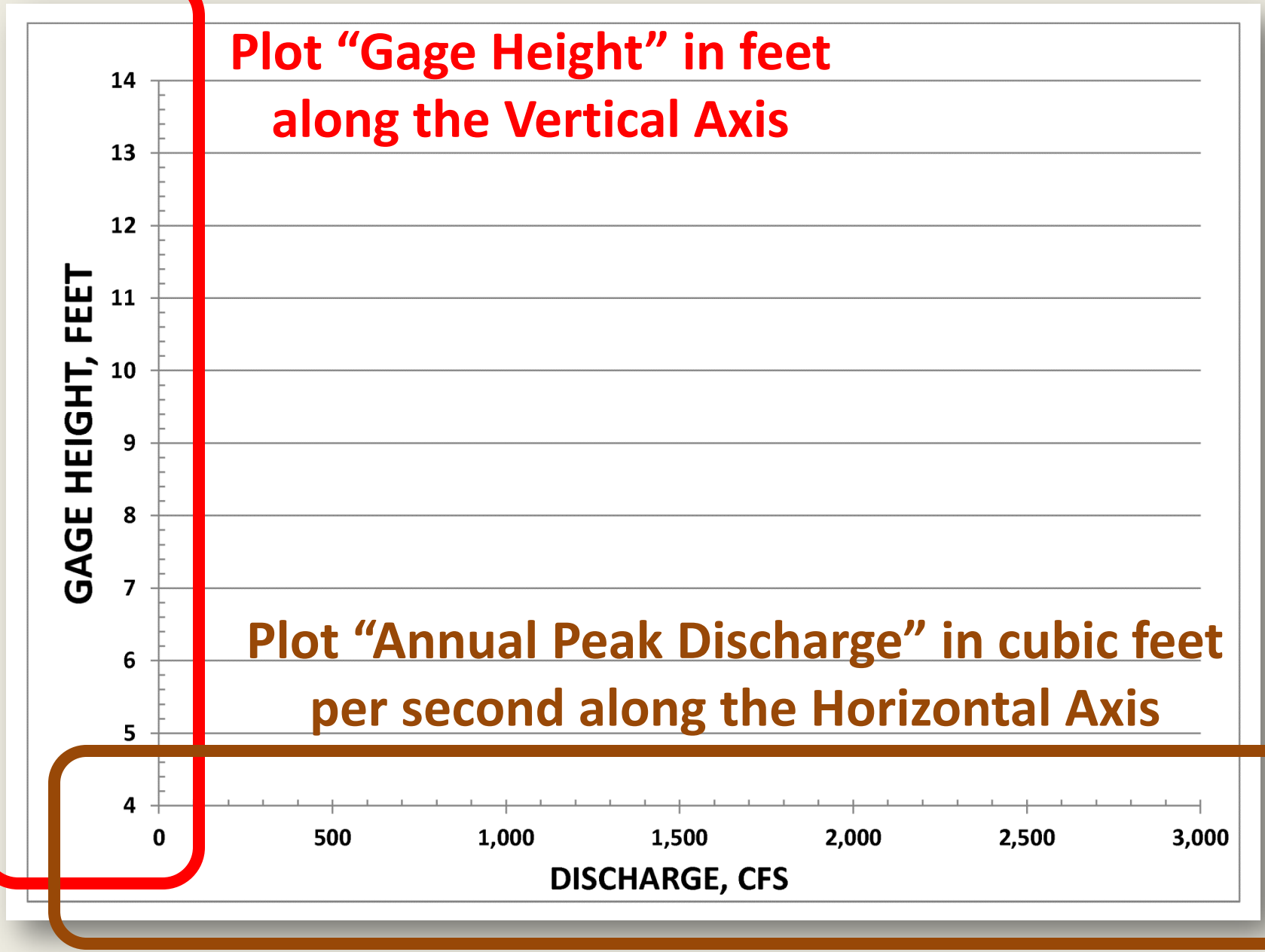
U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION:03329700 DEER CREEK NEAR DELPHI, IN TYPE:STREAM AGENCY:USGS STATE:18 COUNTY:015
LATITUDE: 403525 LONGITUDE: 0863717 NAD27 DRAINAGE AREA:274 CONTRIBUTING DRAINAGE AREA: DATUM:559.81 NGVD29
Date Processed: 2013-06-07 12:10 By dvarvin
Peak Flow Report

WATER YEAR	DATE	TIME	PEAK DISCHARGE (CFS)	DISCHARGE CODES	GAGE HEIGHT (FT)	GAGE HEIGHT CODES	HIGHEST MAX GAGE HEIGHT SINCE	MAX GAGE HEIGHT (FT)	DATE	TIME	GAGE HEIGHT CODES
1943	05/ /1943		18000	B	19.80		1913				
1944	04/12/1944		4700		10.90						
1945	05/16/1945		3250		9.28						
1946	02/14/1946		3500	1							
1947	04/30/1947		3000		9.00						
1948	02/28/1948		2720		8.57						
1949	01/19/1949		5580		11.66						
1950	01/04/1950		9160		14.40						
1951	02/21/1951		2950		8.73						
1952	04/24/1952		5360		11.25						
1953	03/04/1953		3380		9.24						
1954	06/01/1954		1800		7.00						
1955	07/16/1955		2350		7.86						
1956	10/07/1955		4360		10.23						
1957	07/17/1957		4960		10.79						
1958	06/10/1958		14400		18.26						
1959	02/10/1959		12100		16.72						
1960	08/03/1960		3230		8.64						
1961	04/23/1961		3080		8.43						
1962	01/27/1962		3630		9.13	2		11.72	01/26/1962		1
1963	03/04/1963		5800		11.58						
1964	04/21/1964		3230		8.57						
1965	04/09/1965		1980		6.44						
1966	06/27/1966		590		4.25						
1967	12/09/1966		3100		7.88						
1968	05/16/1968		7670		13.34						
1969	01/29/1969		6510		11.68						
1970	05/13/1970		4050		9.22						
1971	02/05/1971		2900		7.97						
1972	04/22/1972		3640		8.77						
1973	06/05/1973		4330		9.53						
1974	01/20/1974		5950		11.21						
1975	06/15/1975		3750		8.90						
1976	02/17/1976		3670		8.80						
1977	03/04/1977		1260		5.60						

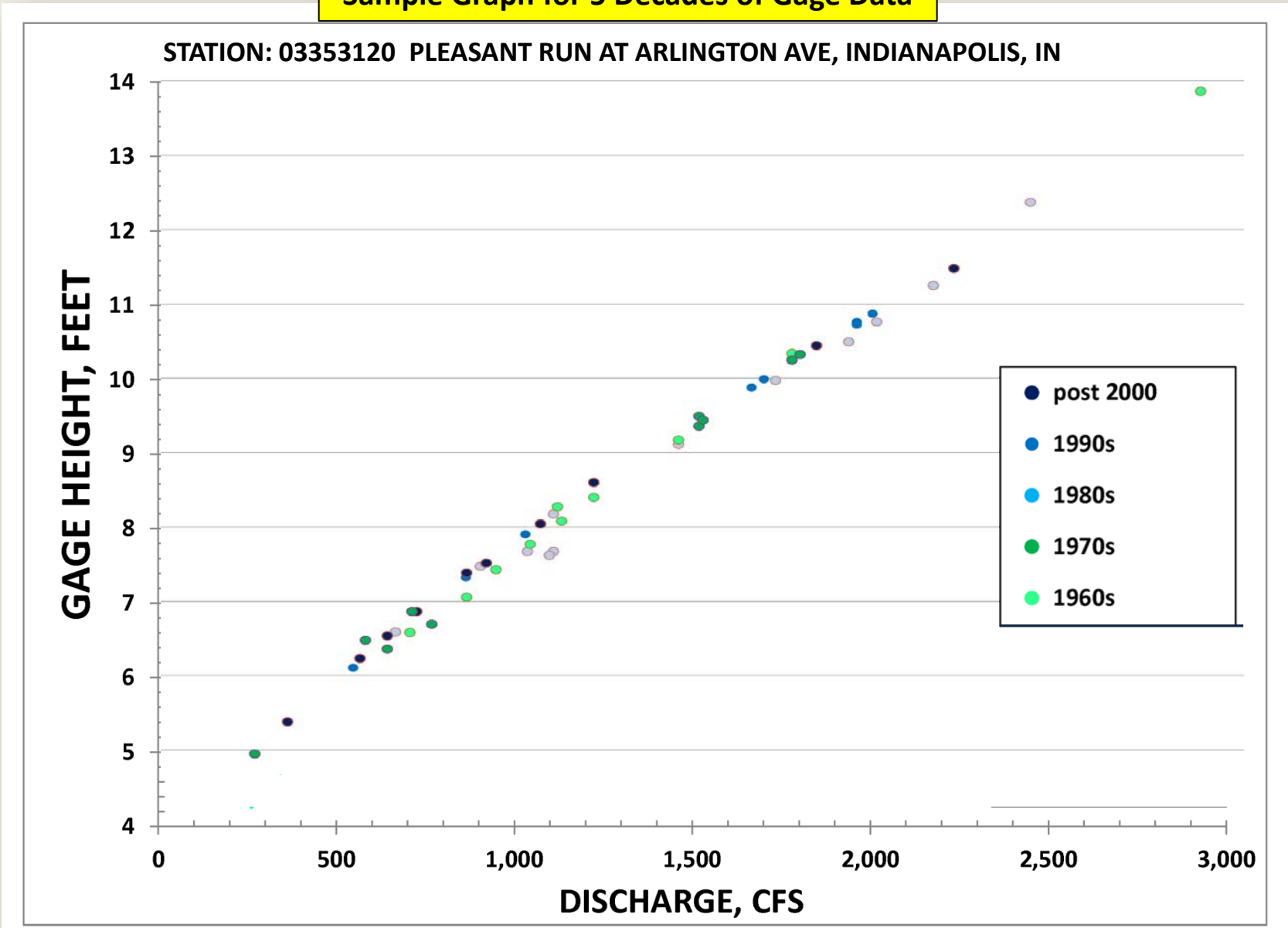


Plotting Annual Peak Gage Height vs. Discharge



Plotting Annual Peak Gage Height vs. Discharge

Sample Graph for 5 Decades of Gage Data



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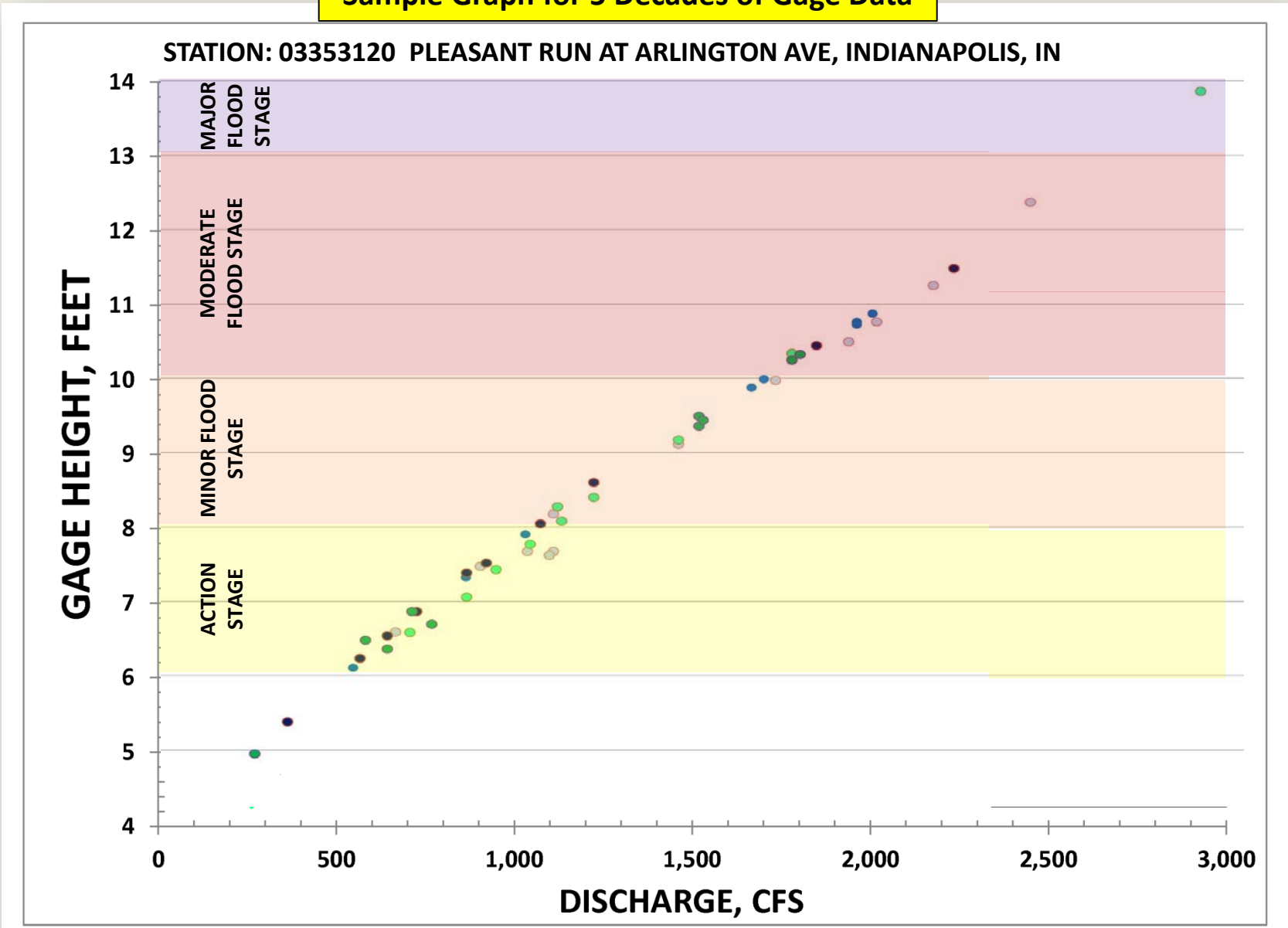
Sample Graph for 5 Decades of Gage Data



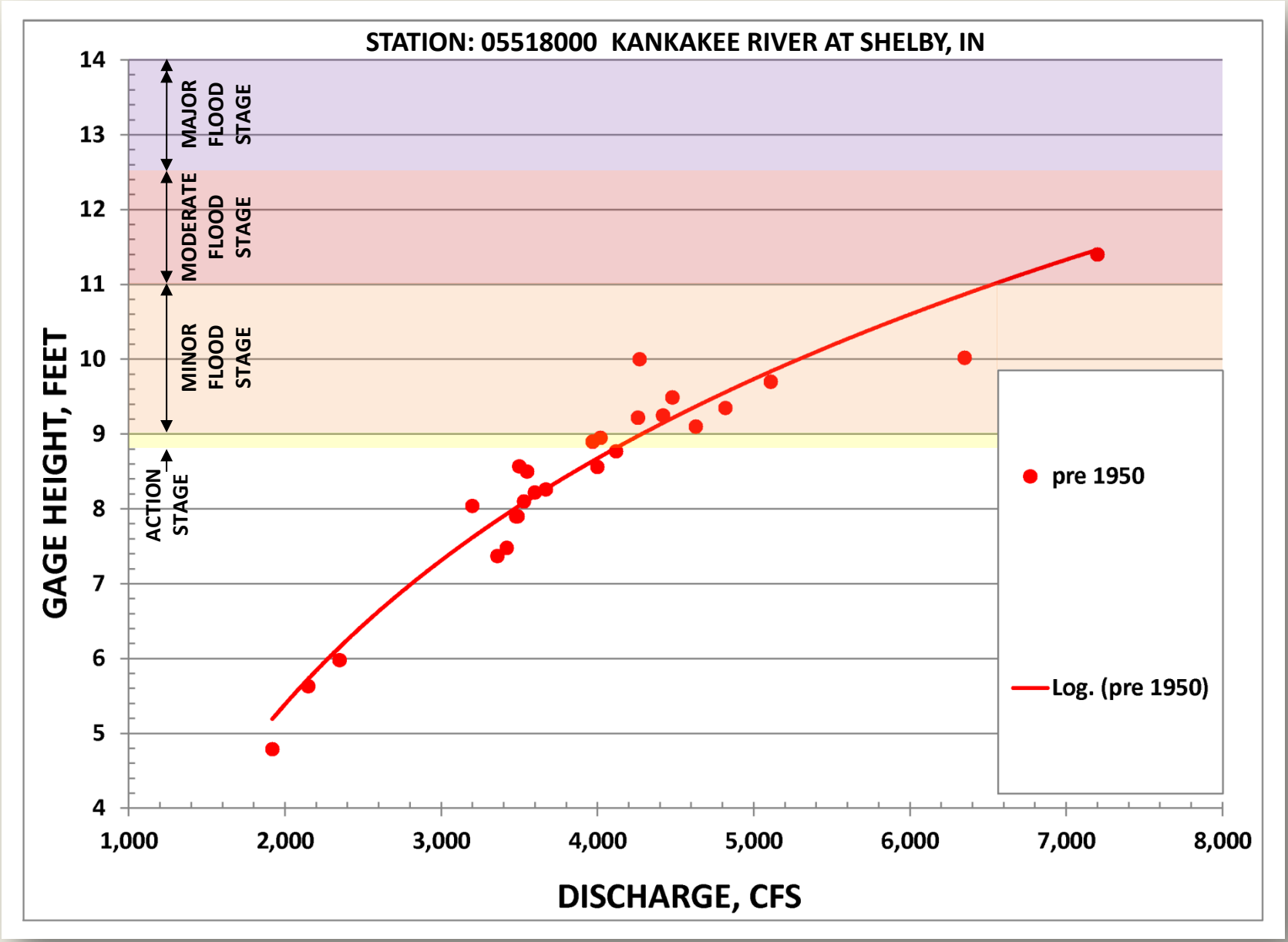
Plots of Annual Peak Discharge vs. Gage Height Showed…?

Four Categories of Findings:

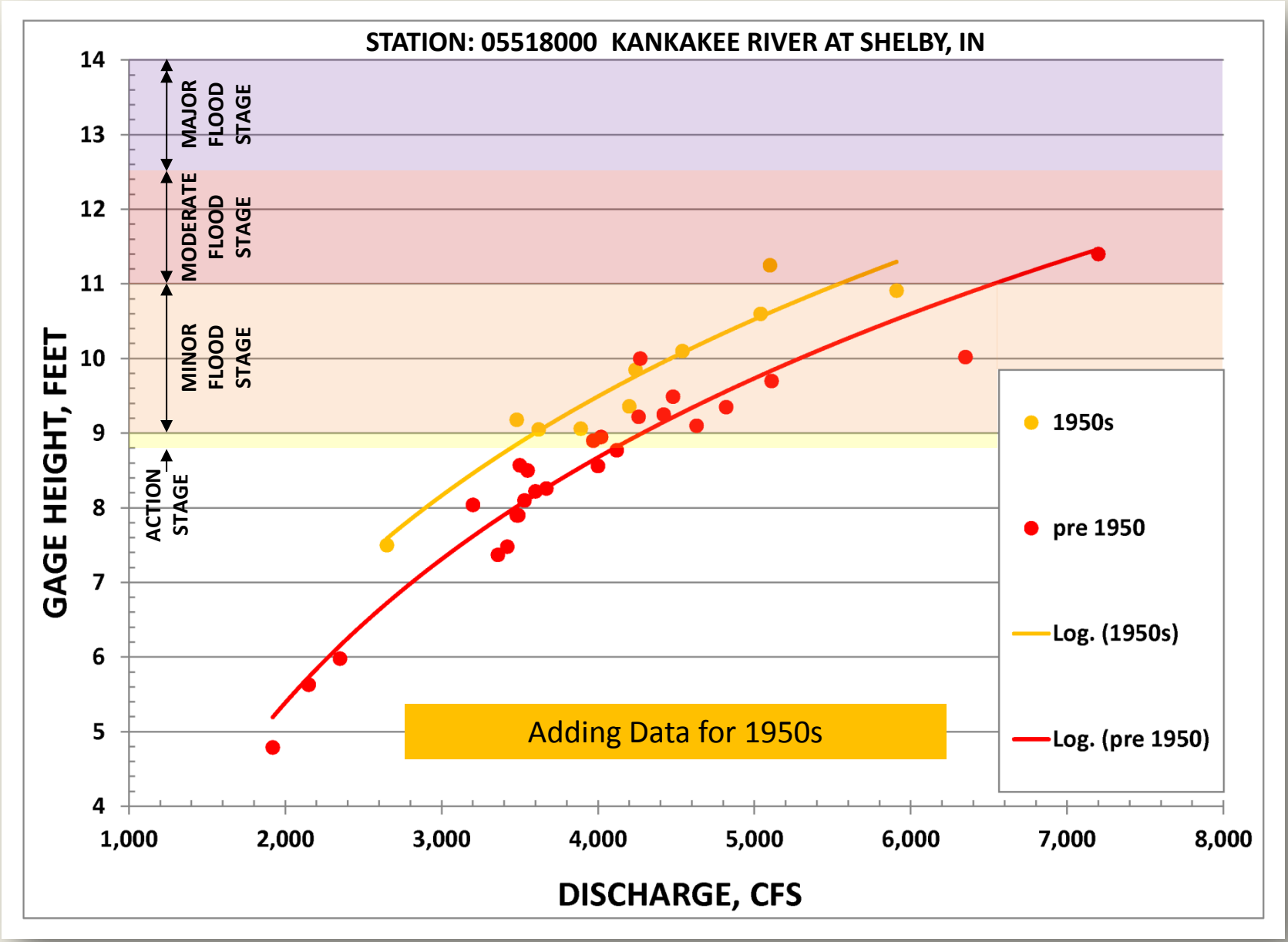
- ***Category 1:*** Minor changes over time or shifting back & forth within a narrow range
- ***Category 2:*** Downward trend over time
- ***Category 3:*** Scattered but upward trend over time
- ***Category 4:*** Upward jump at identified point in time

Samples of Categories 3 and 4 follow…

Category 3: Scattered but Upward Trend



Category 3: Scattered but Upward Trend (cont'd.)



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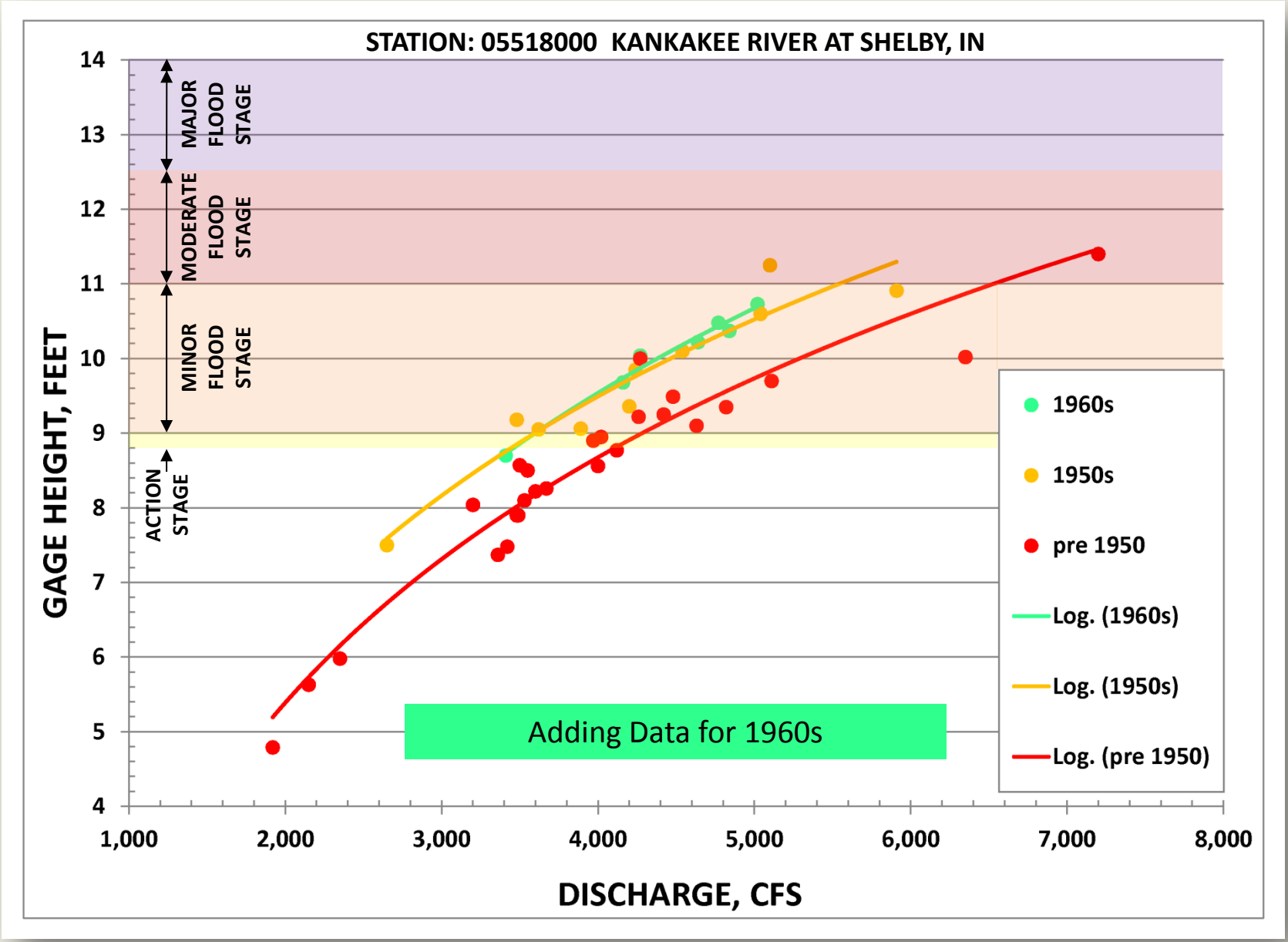

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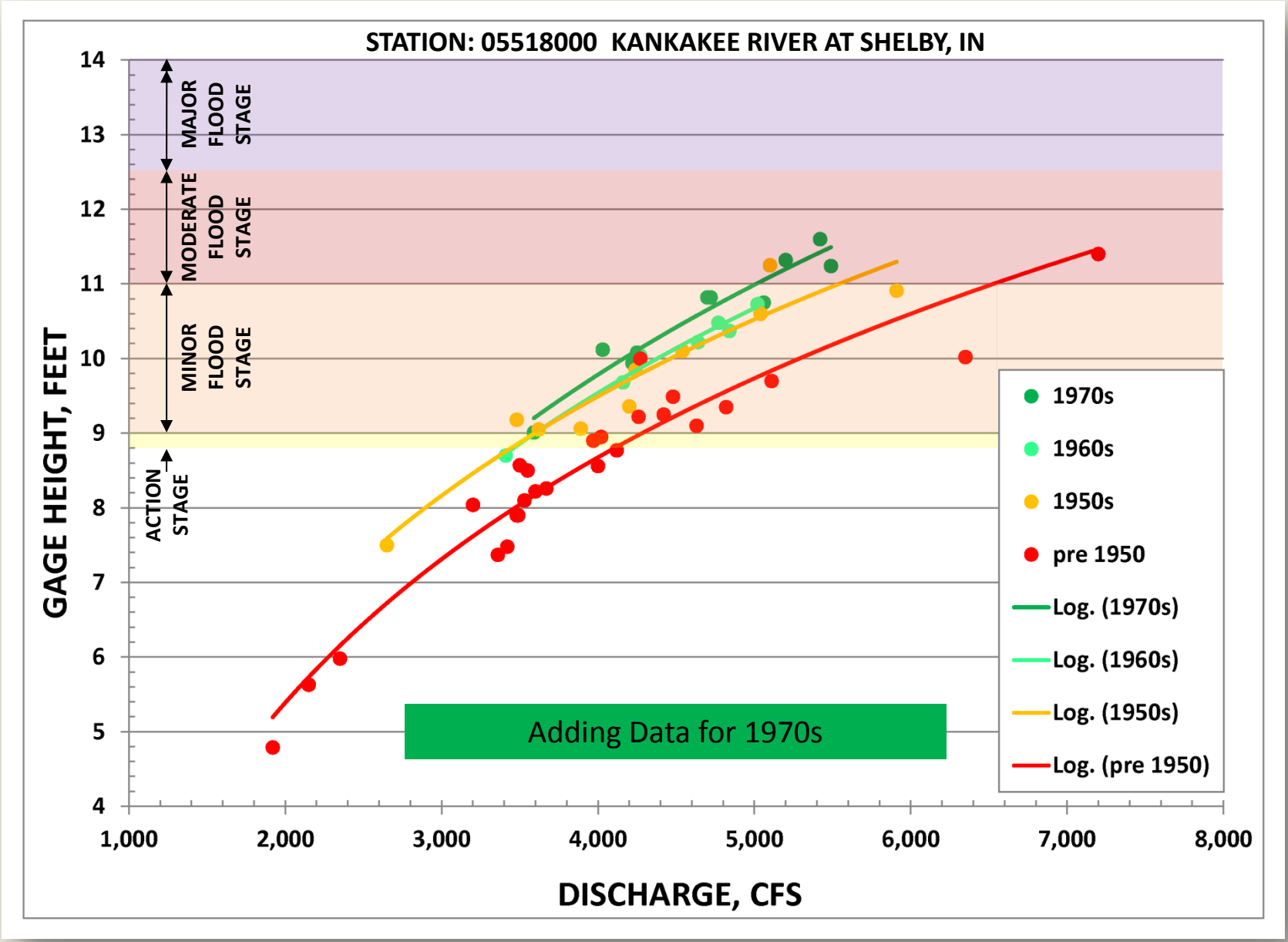

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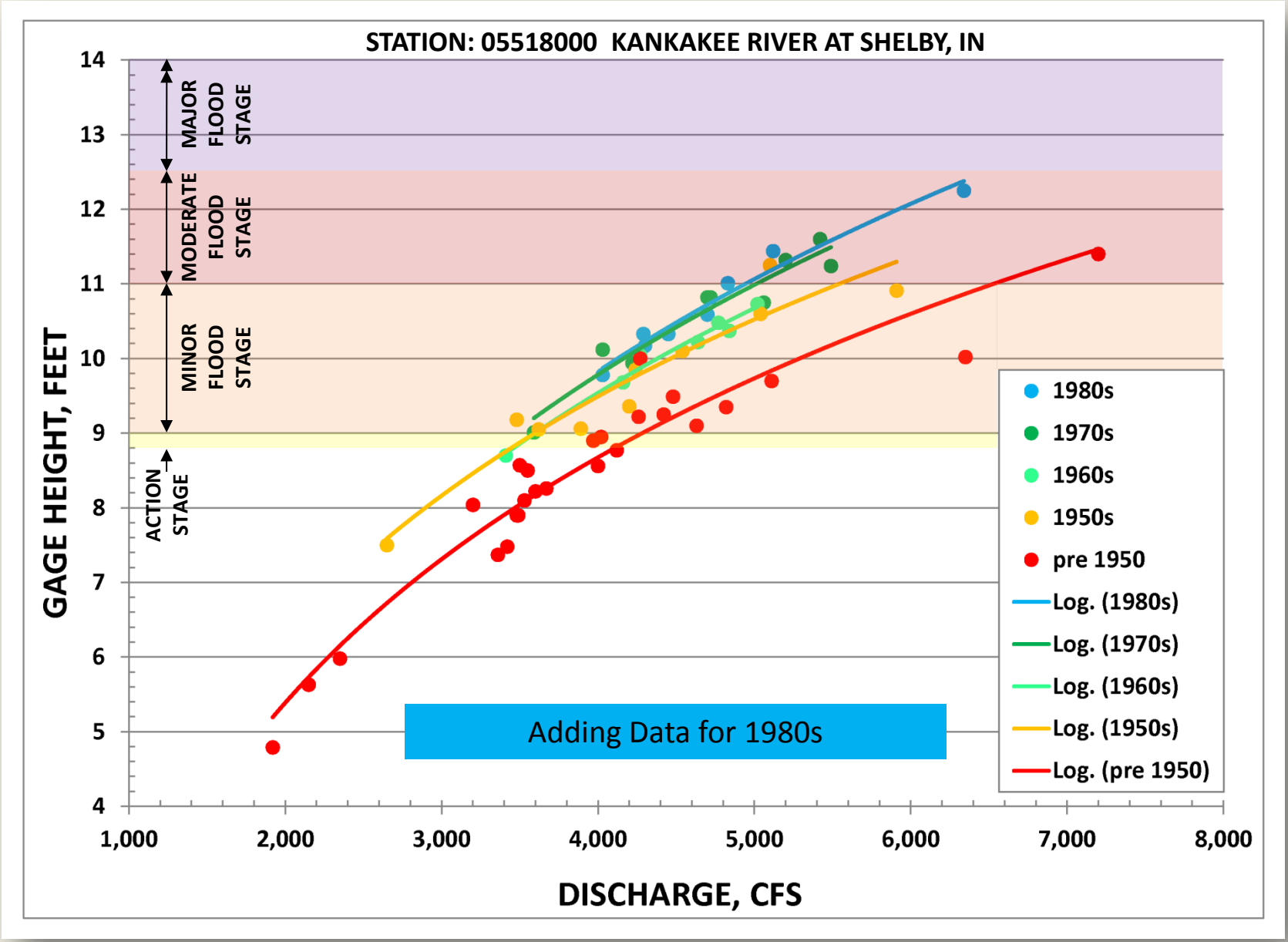

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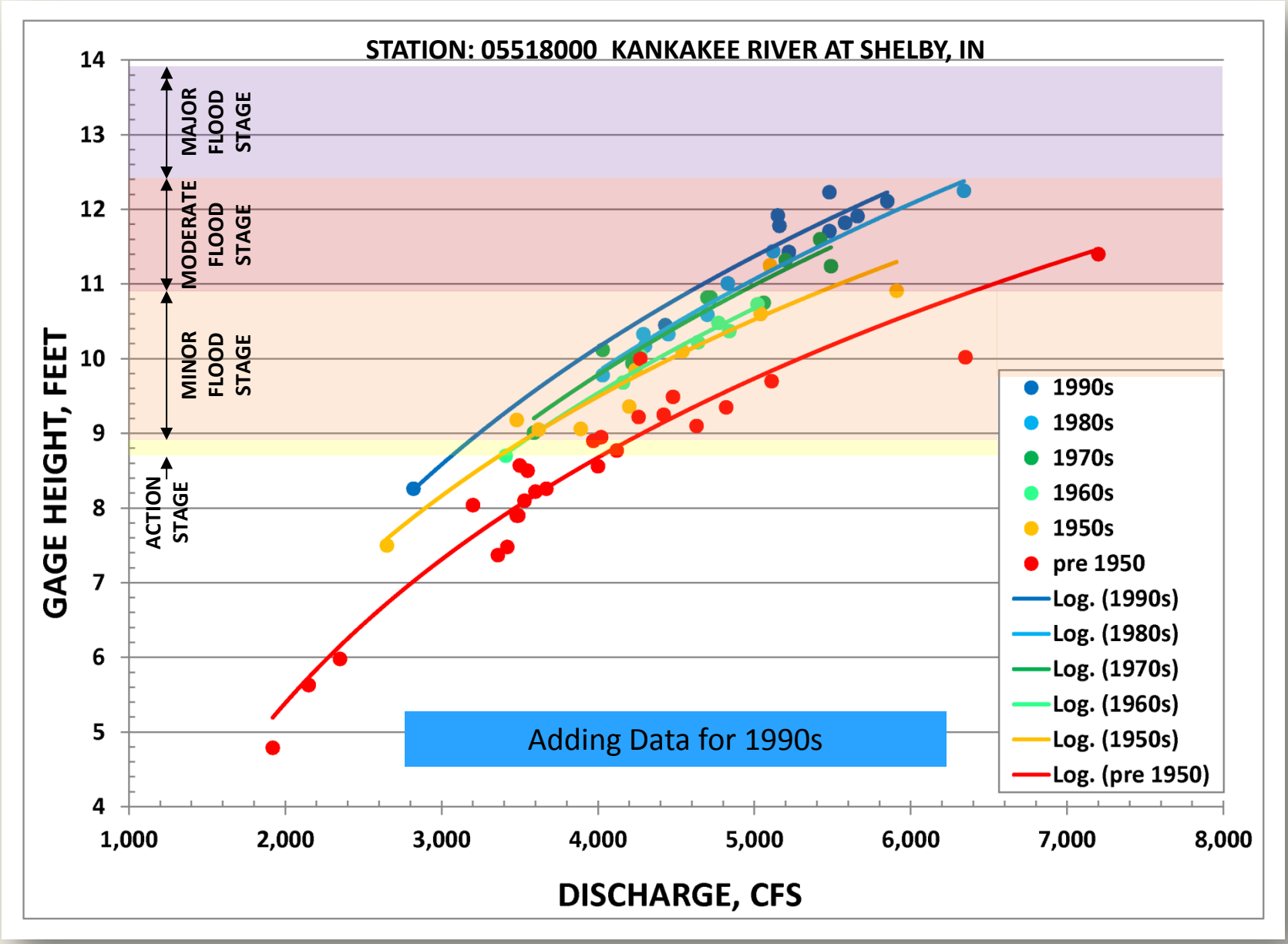

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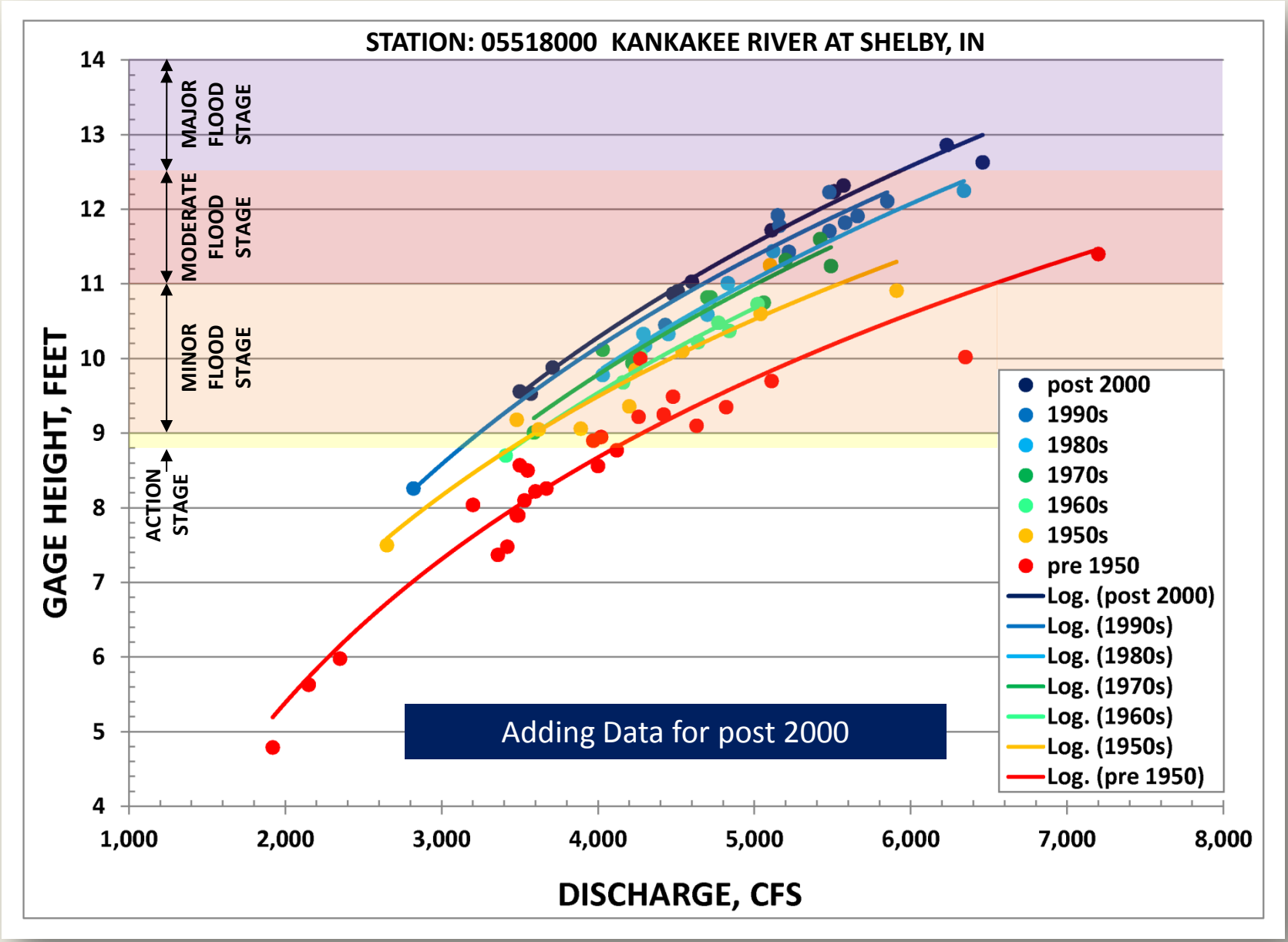

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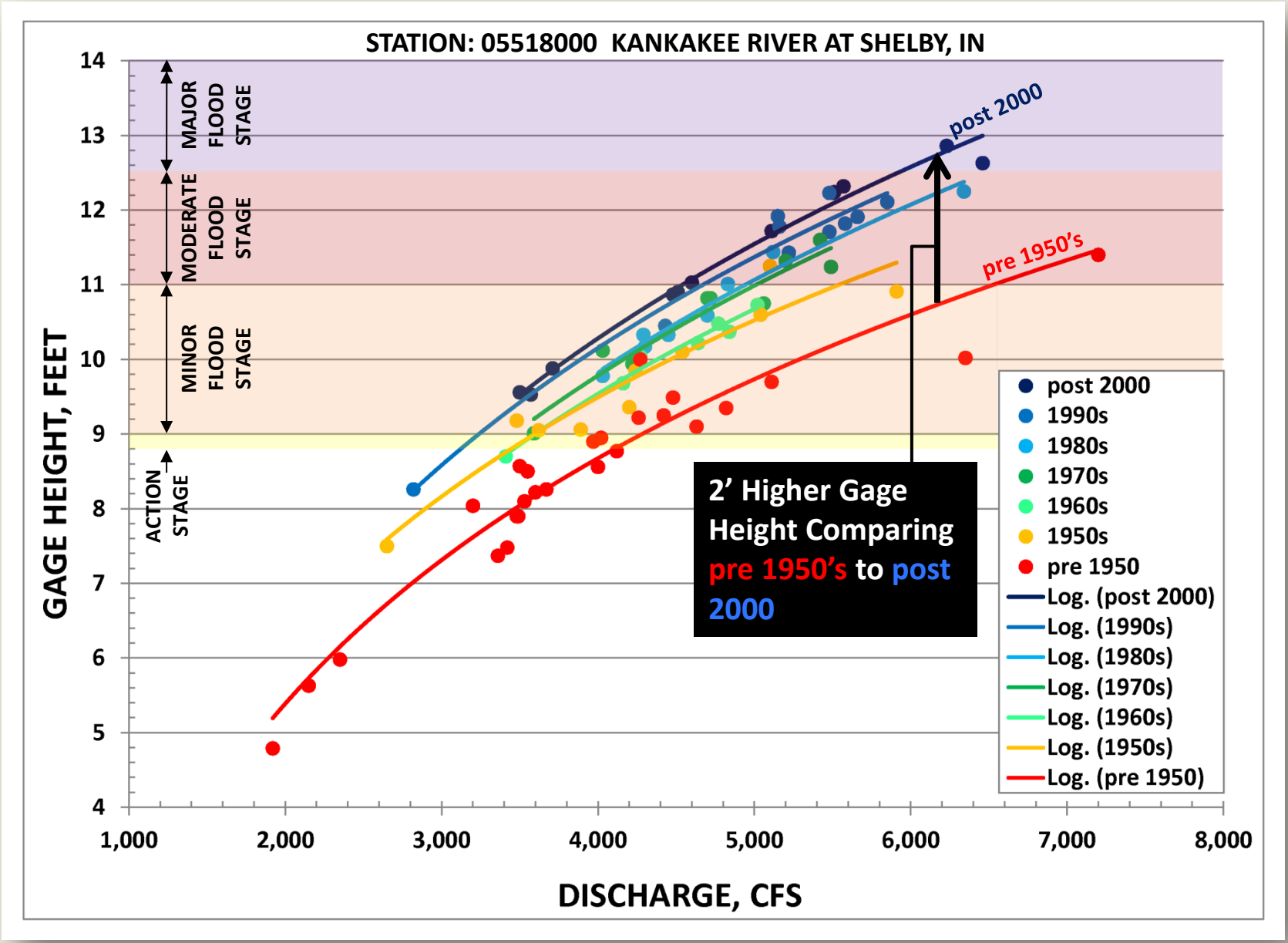
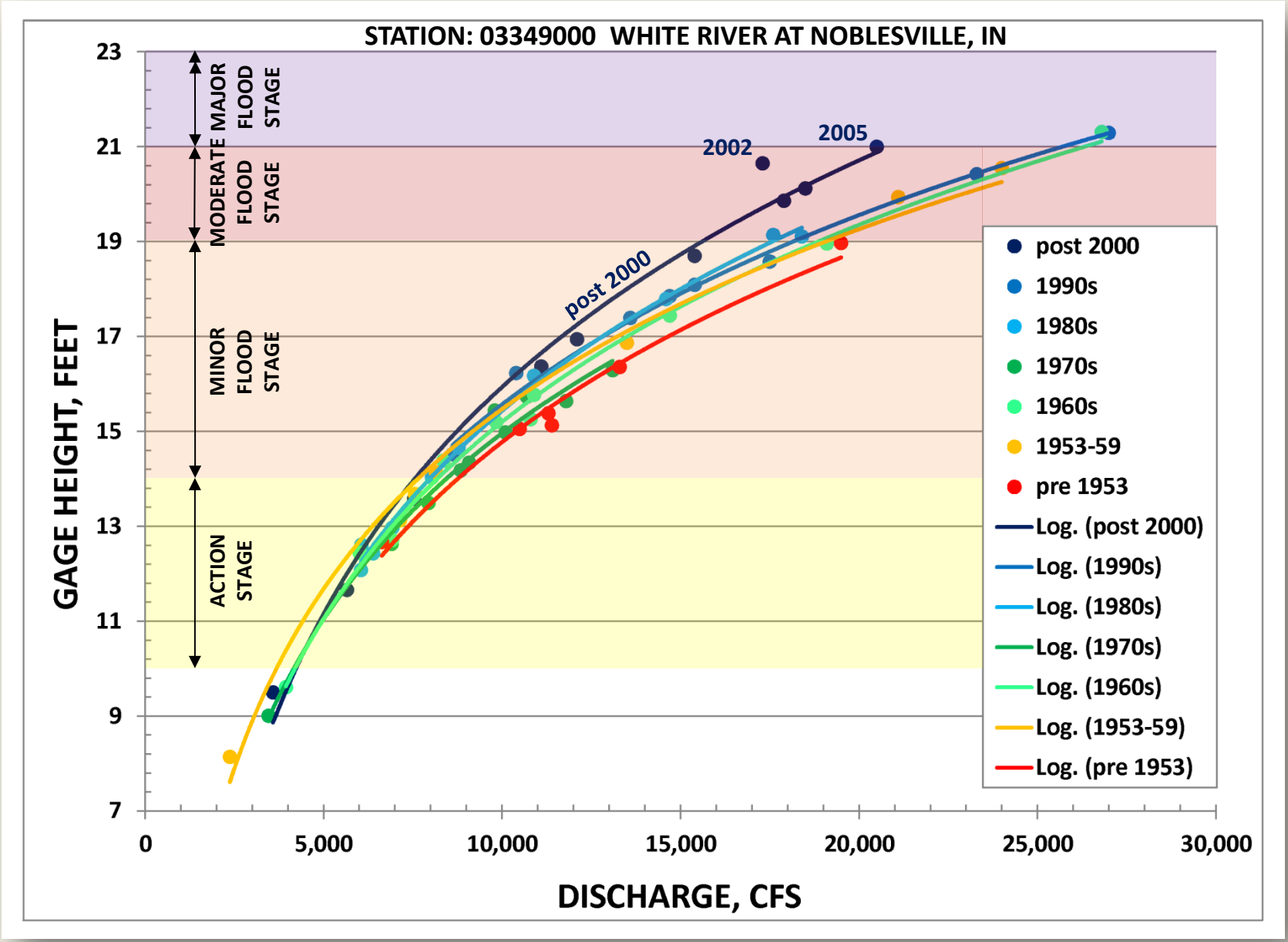
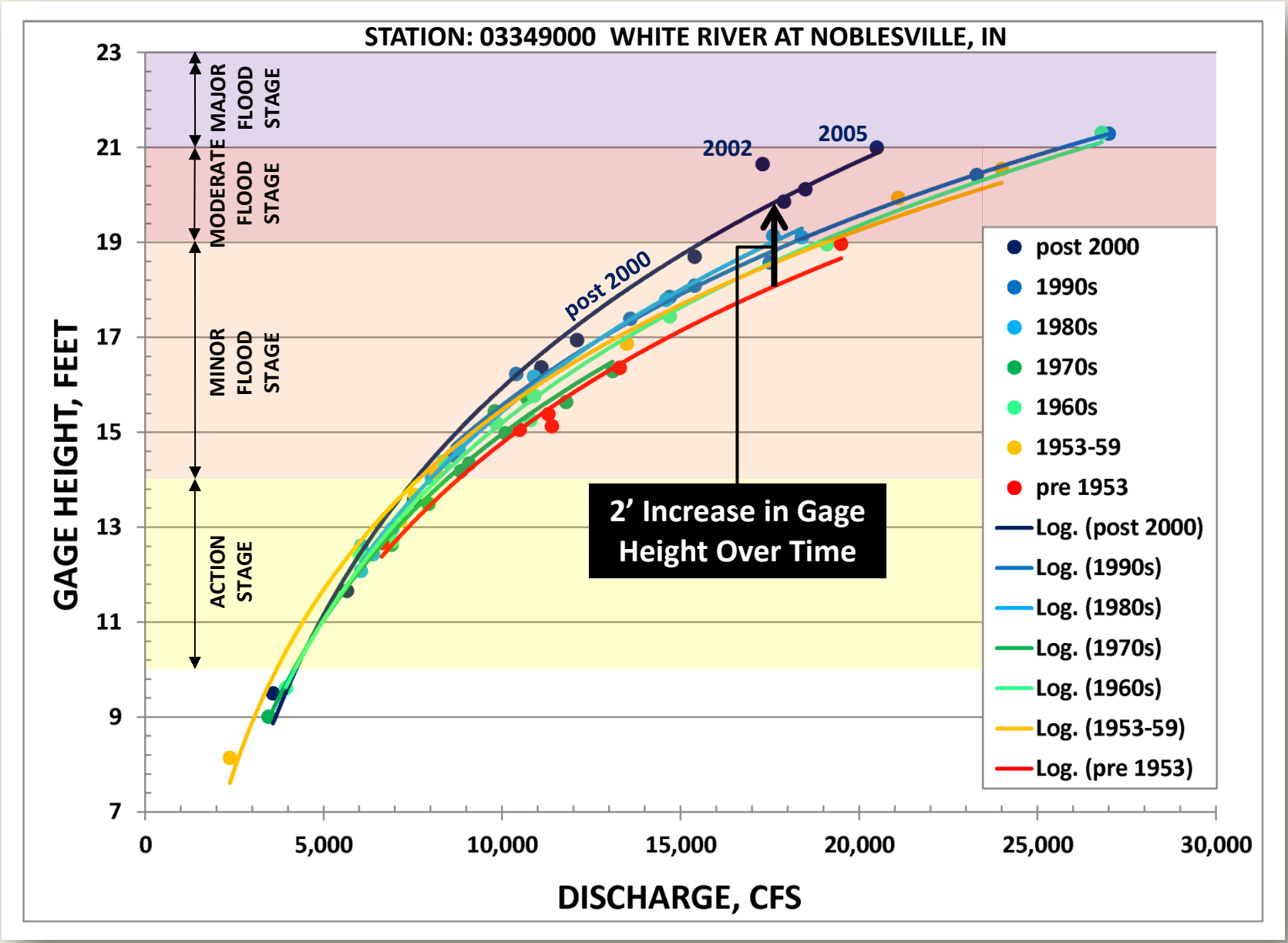


Category 3: Upward Trend with an Outlier



Category 3: Upward Trend with an Outlier (cont'd.)



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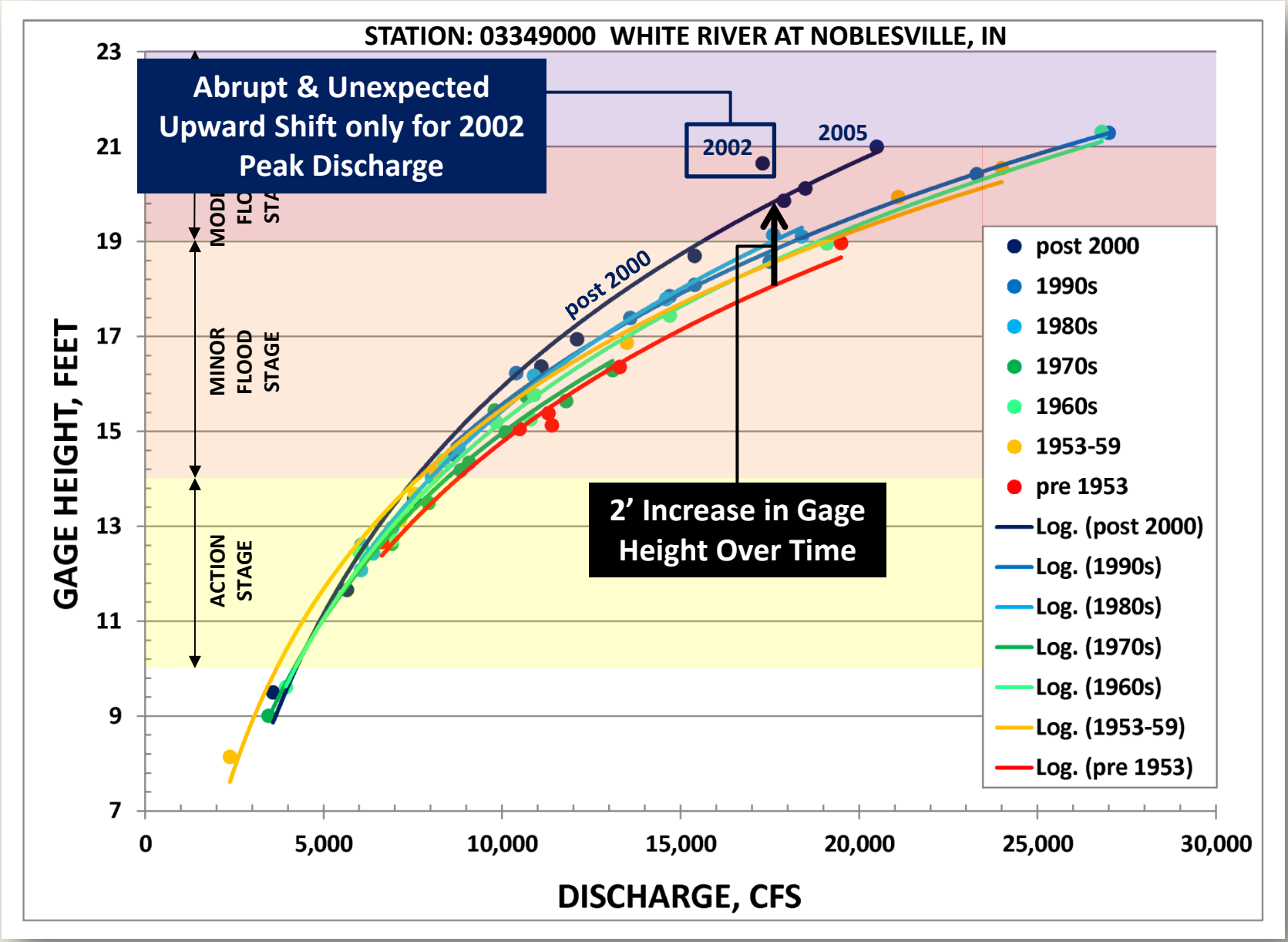

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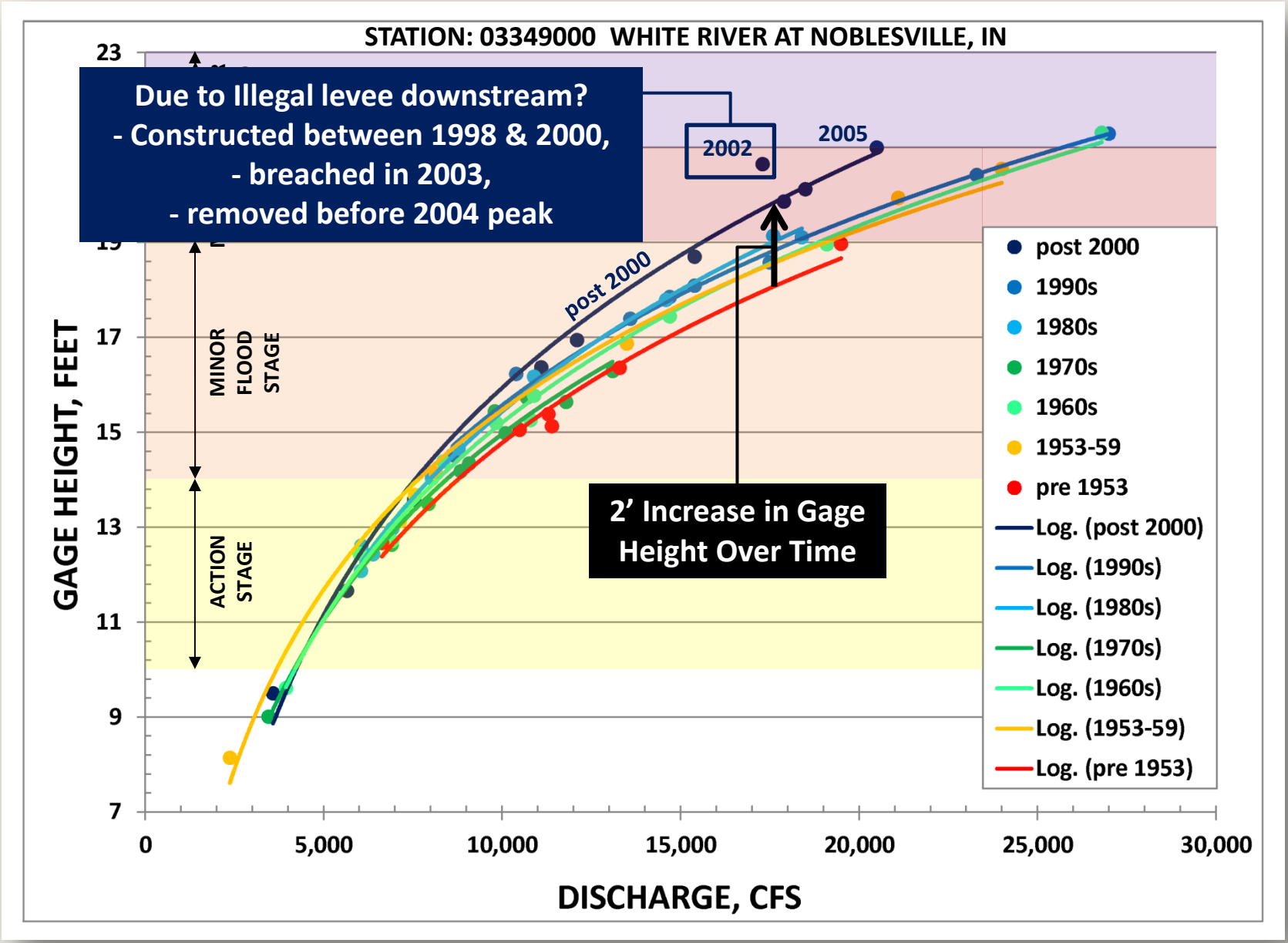
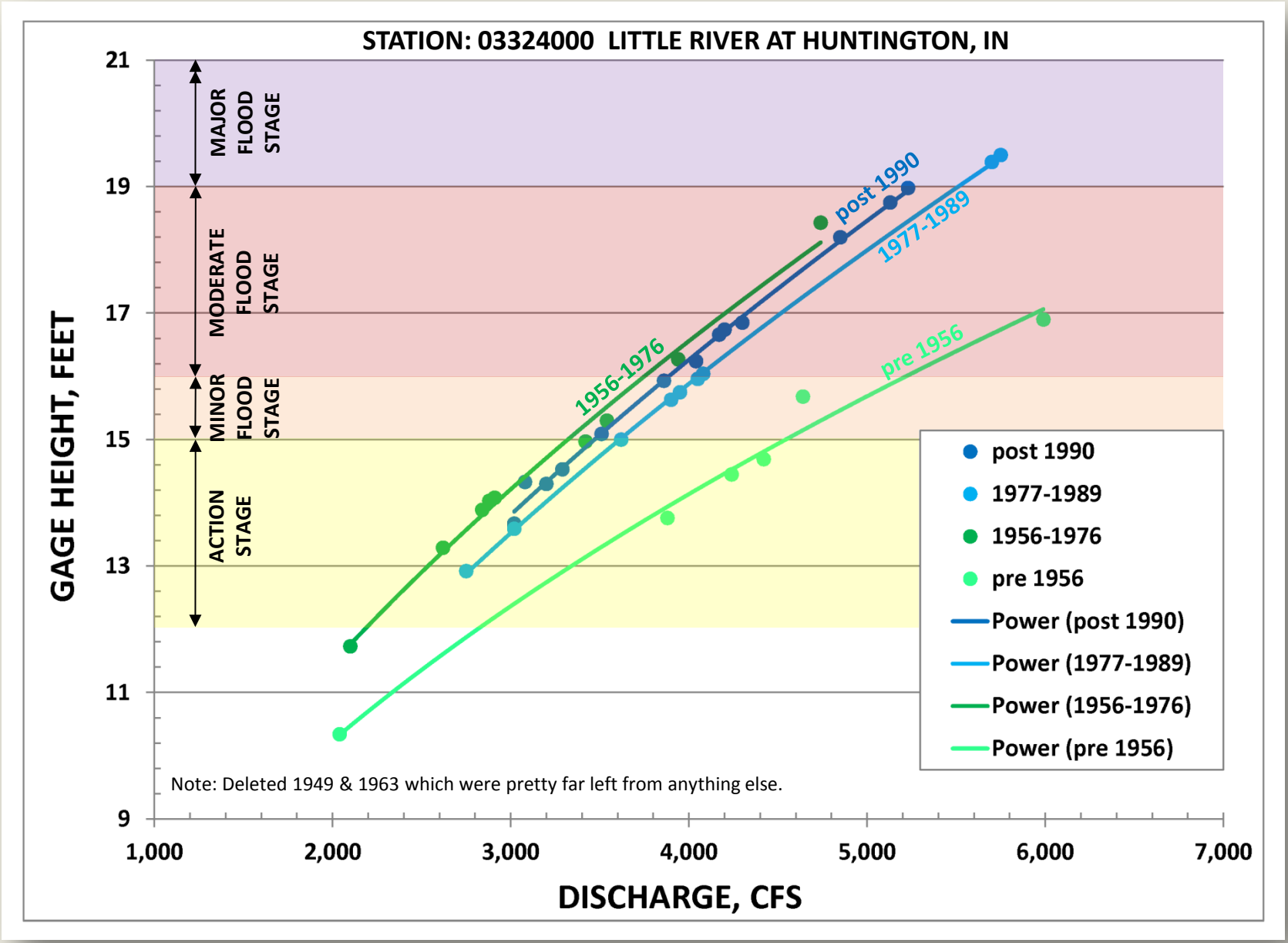
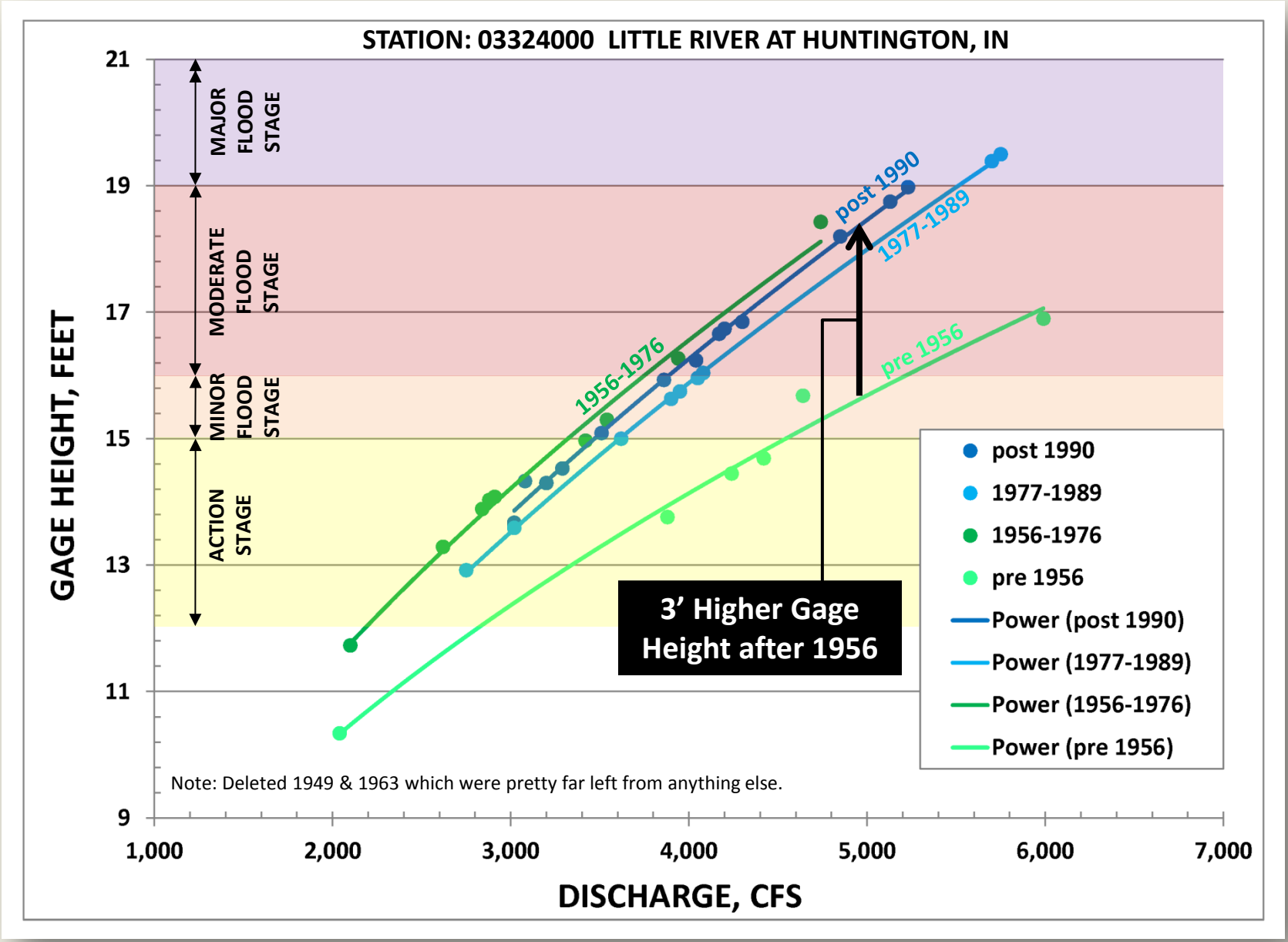


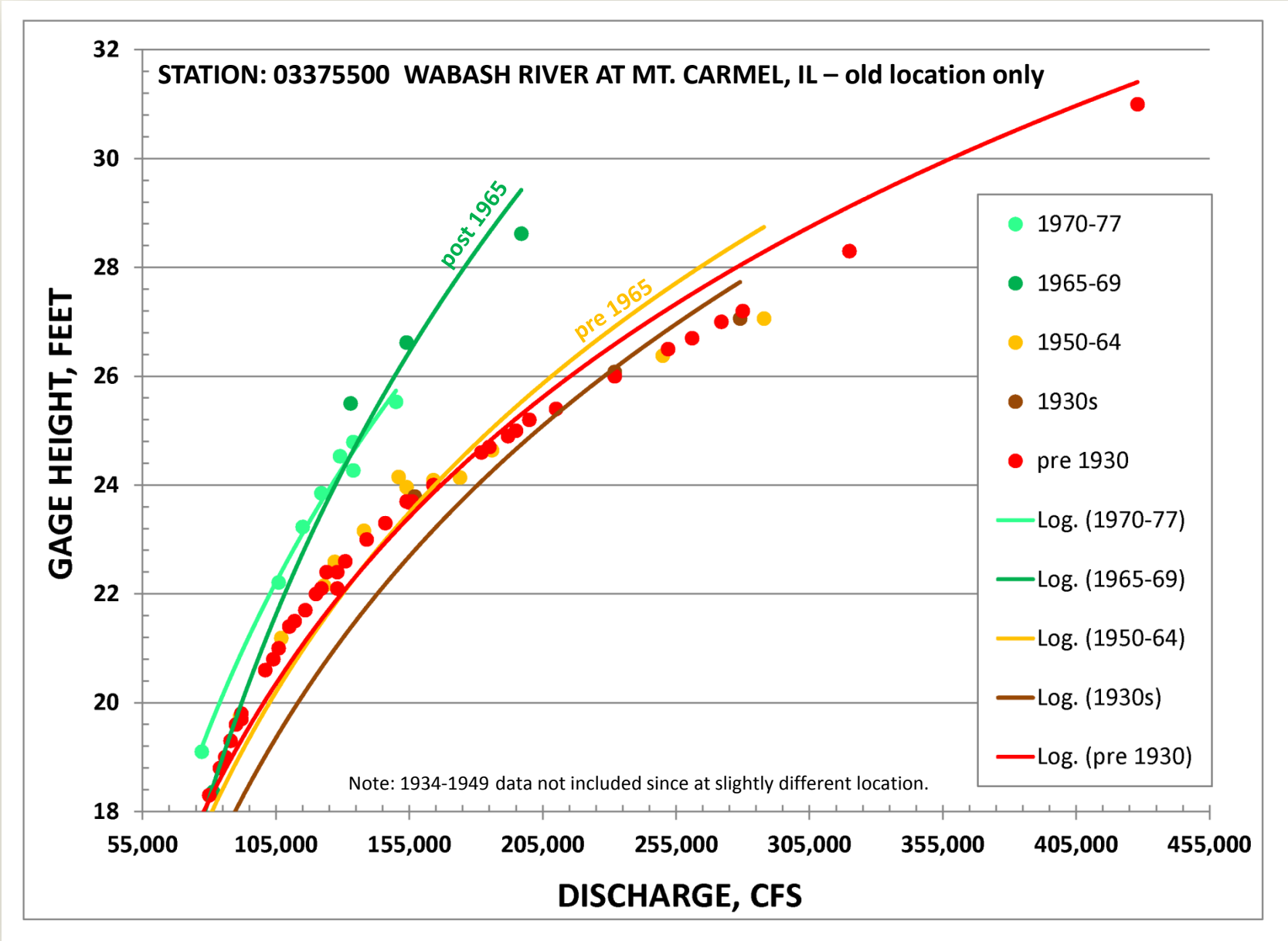
Category 4: Upward Jump



Category 4: Upward Jump (cont.)



Category 4: Upward Jump at Identified Point in Time



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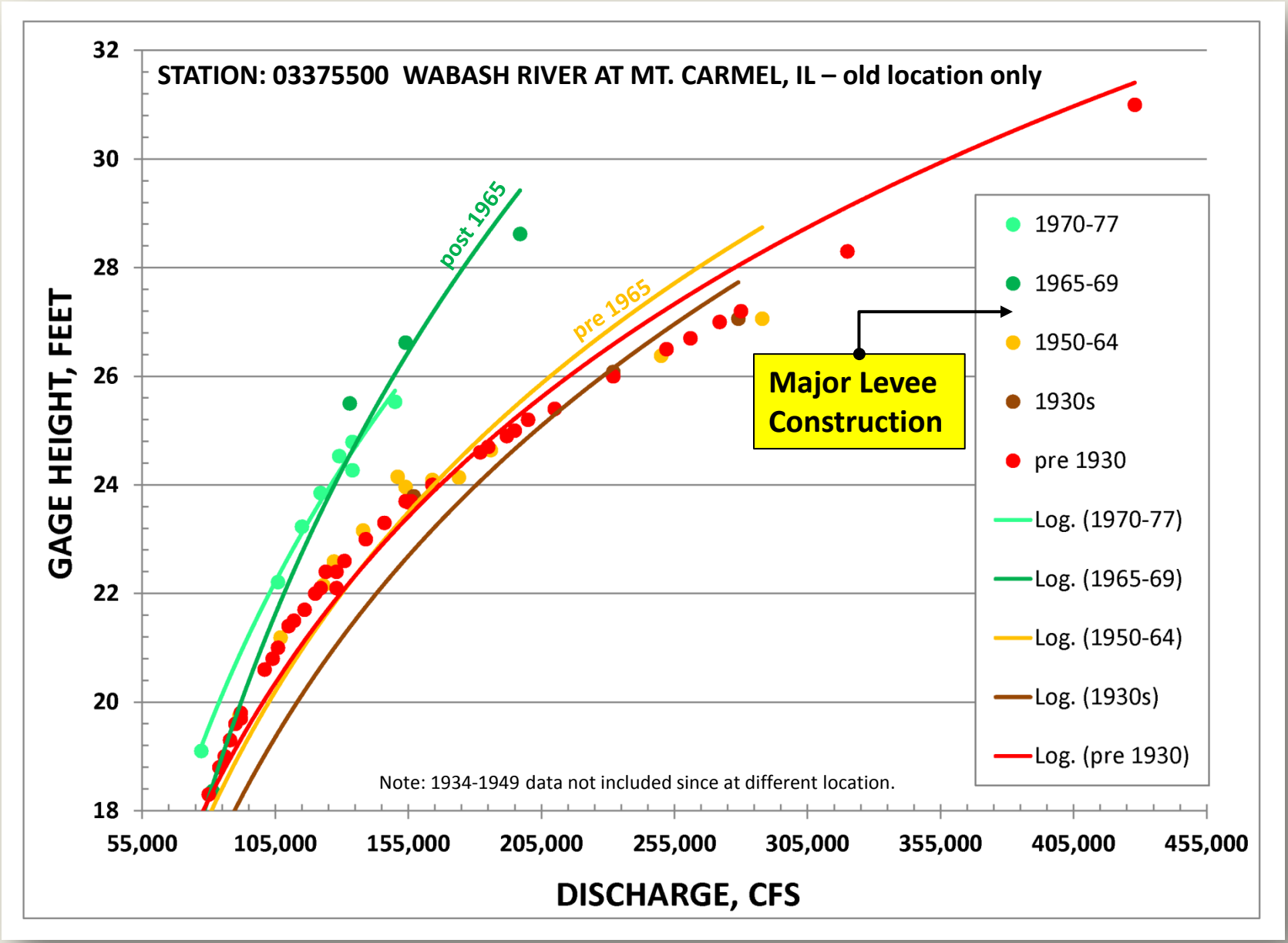
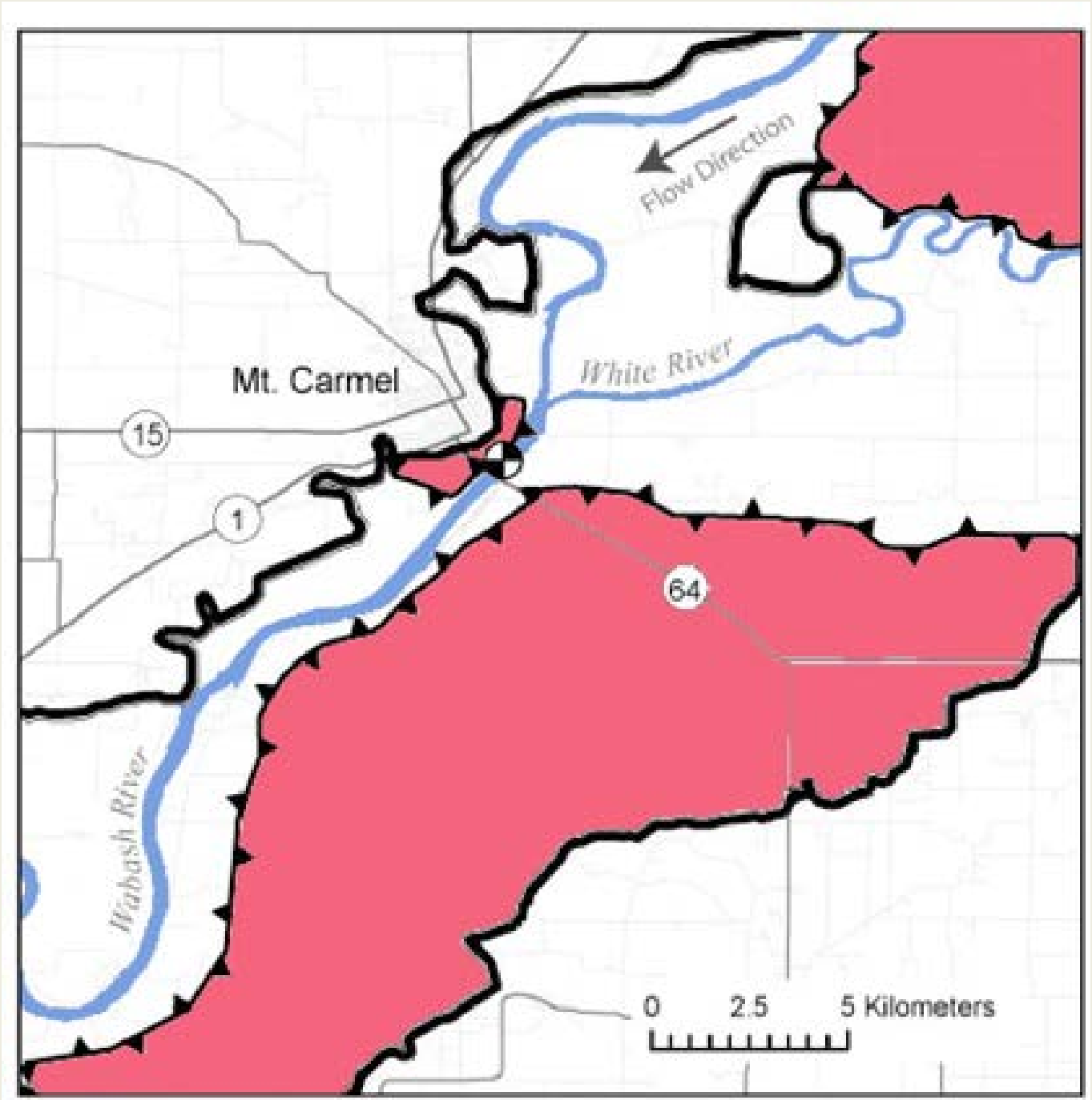
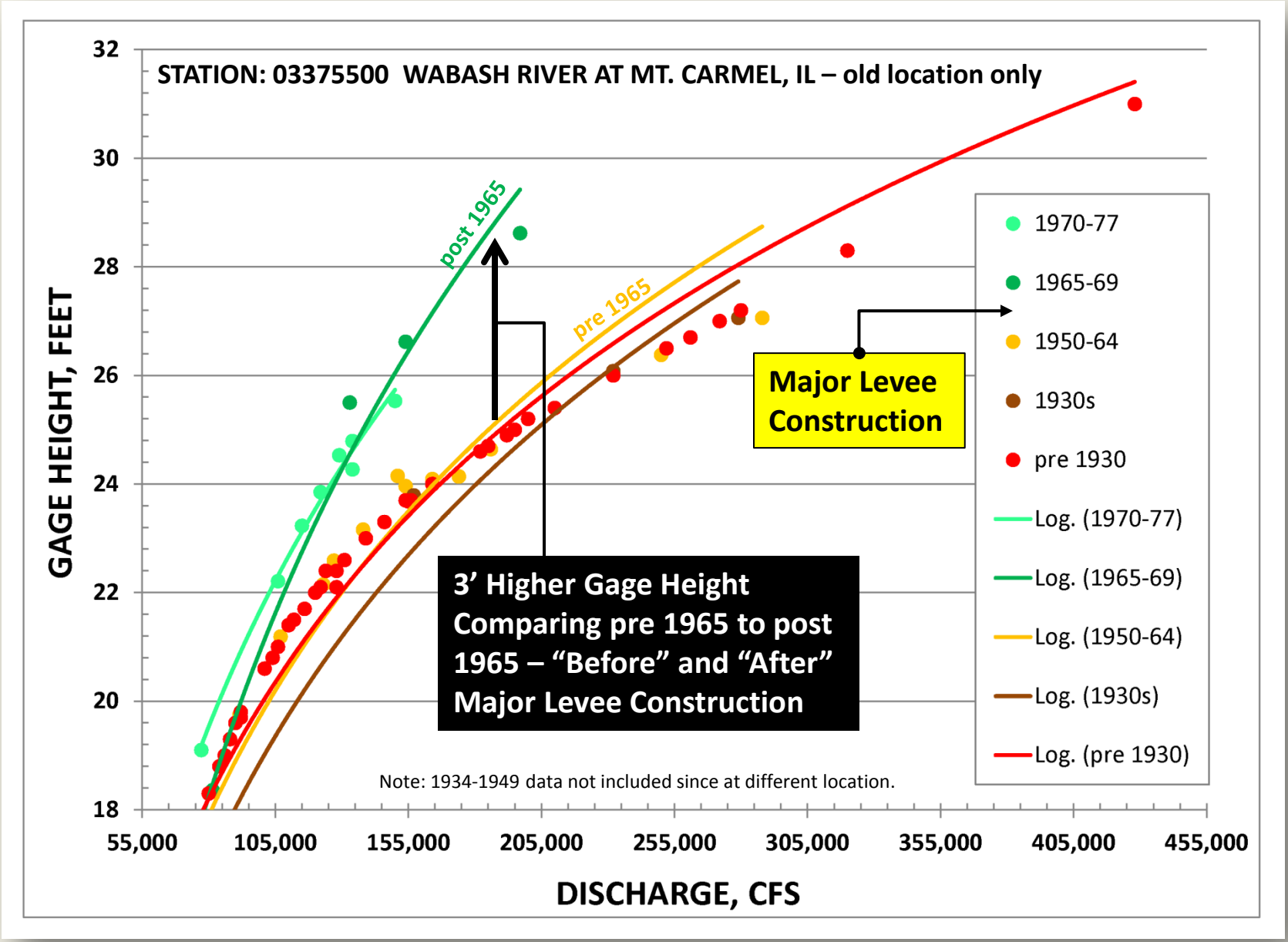
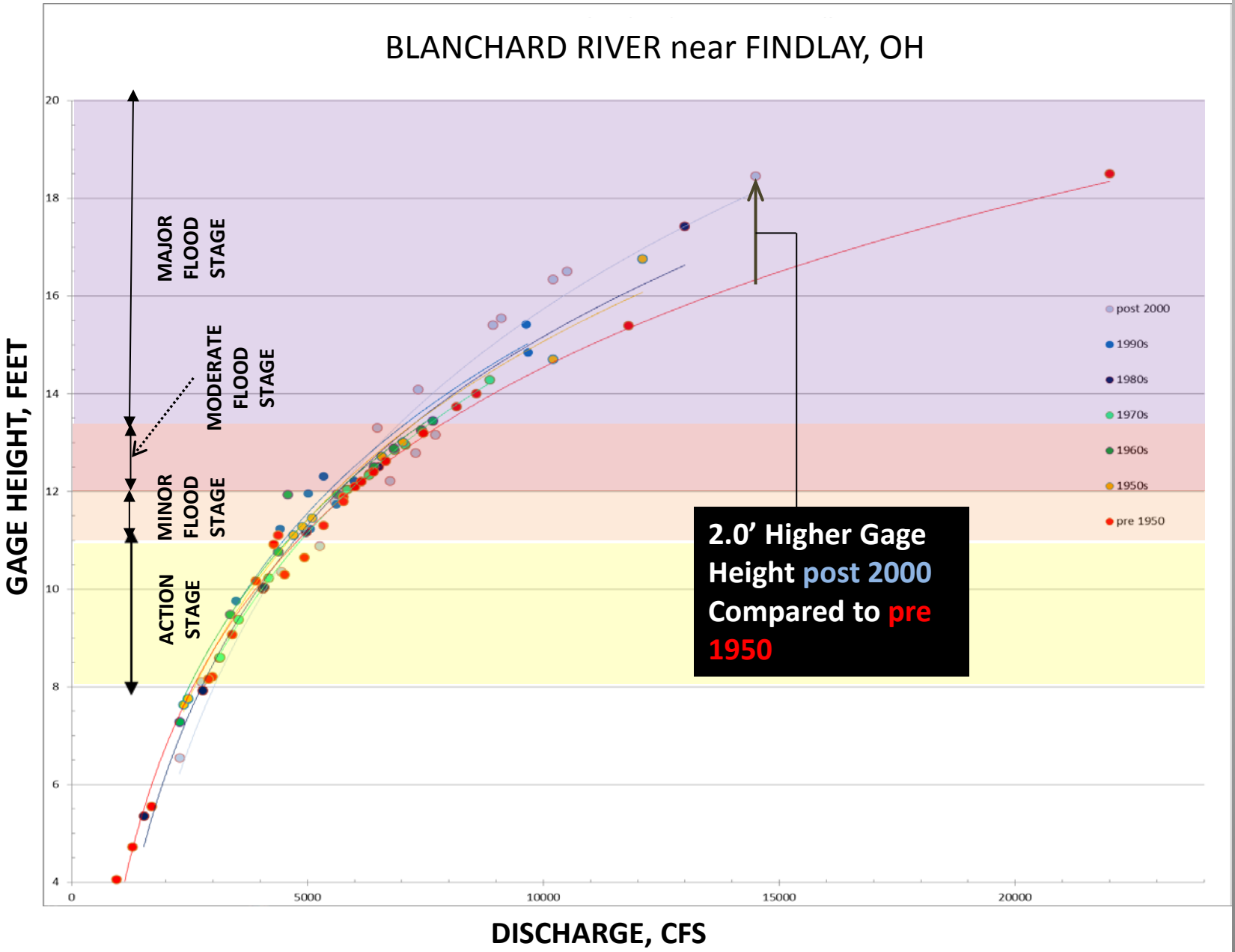
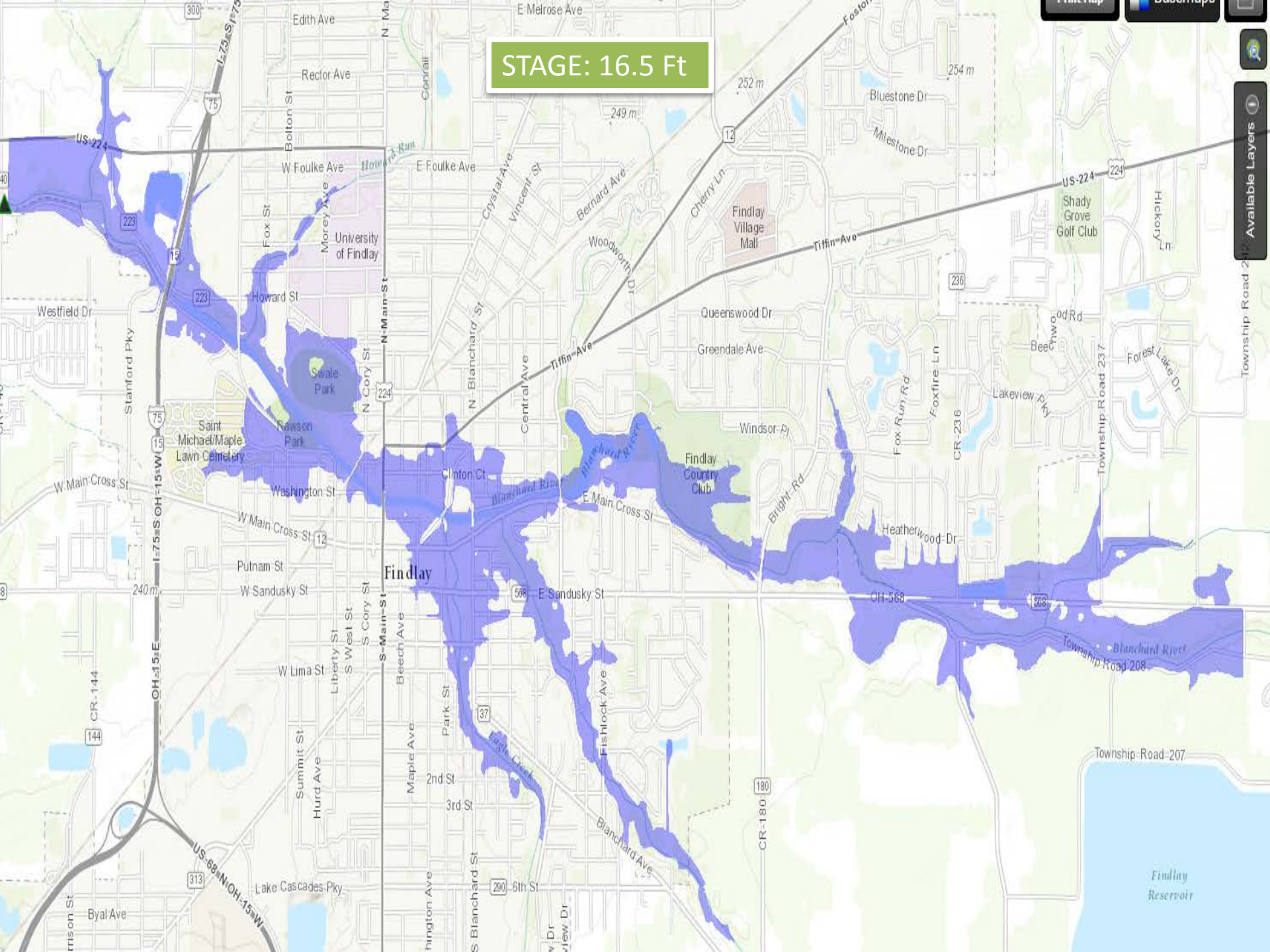


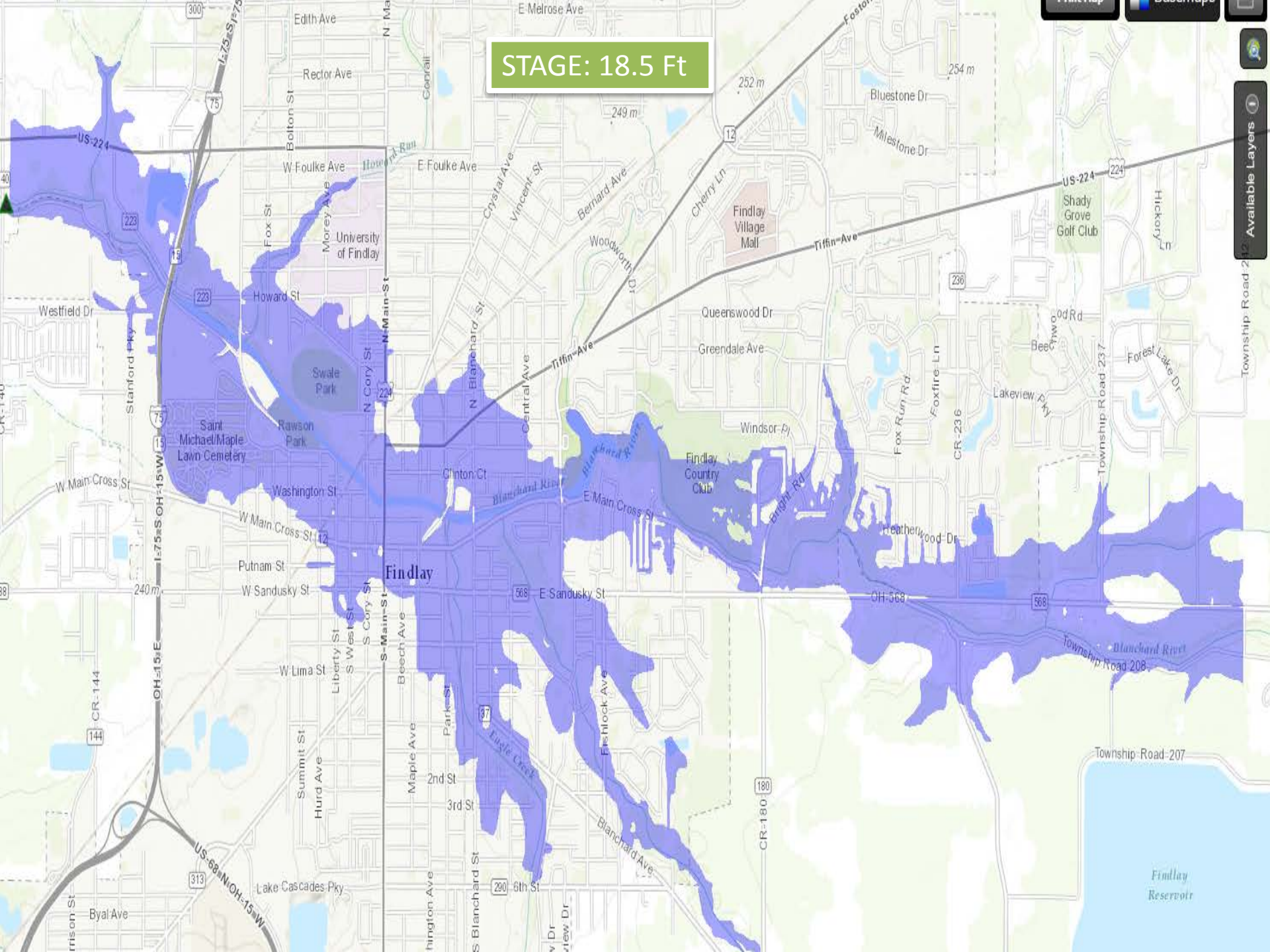

Flow Direction
Mt. Carmel
White River
15
1
64
Wabash River
0
2.5
5 Kilometers

Category 4: Upward Jump at Identified Point in Time




BLANCHARD RIVER near FINDLAY, OH
GAGE HEIGHT, FEET
DISCHARGE, CFS
MAJOR FLOOD STAGE
MODERATE FLOOD STAGE
MINOR FLOOD STAGE
ACTION STAGE
2.0' Higher Gage Height post 2000 Compared to pre 1950
post 2000
1990s
1980s
1970s
1960s
1950s
pre 1950
20
18
16
14
12
10
8
6
4
0
5000
10000
15000
20000


STAGE: 16.5 Ft
Findlay
Edith Ave
E Melrose Ave
Rector Ave
Bolton St
Conrail
US-224
W Foulke Ave
E Foulke Ave
Howard Run
Fox St
Morey Ave
University of Findlay
Howard St
Westfield Dr
Stanford Pky
I-75 S OH-15 W
Swale Park
Rawson Park
Saint Michael/Maple Lawn Cemetery
N Cory St
N Main St
N Blanchard St
Crystal Ave
Vincent St
Bernard Ave
Woodworth Dr
Cherry Ln
Central Ave
Tiffin Ave
Findlay Village Mall
Bluestone Dr
Milestone Dr
Shady Grove Golf Club
Hickory Ln
Township Road 237
Queenswood Dr
Greendale Ave
Windsor Pl
Foxfire Ln
Fox Run Rd
CR-236
Lakeview Pky
Forest Lake Dr
Findlay Country Club
Blanchard River
Clinton Ct
Washington St
W Main Cross St
E Main Cross St
Bright Rd
Heatherwood Dr
OH-568
Township Road 208
Putnam St
W Sandusky St
E Sandusky St
W Lima St
Liberty St
S West St
S Cory St
Beech Ave
Maple Ave
Park St
Fishlock Ave
Eagle Creek
2nd St
3rd St
6th St
Blanchard Ave
CR-180
Township Road 207
Findlay Reservoir
CR-144
OH-15 E
Summit St
Hurd Ave
US-68 N OH-15 W
Lake Cascades Pky
Byal Ave
Available Layers


STAGE: 18.5 Ft
Available Layers
Findlay
Tiffin Ave
US-224
E Melrose Ave
Edith Ave
Rector Ave
Bolton St
W Foulke Ave
E Foulke Ave
Howard Run
Fox St
Morey Ave
University of Findlay
Howard St
Westfield Dr
Stanford Pky
Swale Park
N Cory St
N Main St
N Blanchard St
Central Ave
Crystal Ave
Vincent St
Bernard Ave
Woodworth Dr
Cherry Ln
Findlay Village Mall
Bluestone Dr
Milestone Dr
Shady Grove Golf Club
Hickory Ln
Queenswood Dr
Greendale Ave
Beechwood Rd
Forest Lake Dr
Township Road 237
Lakeview Pky
Foxfire Ln
Fox Run Rd
CR-236
Windsor Pl
Saint Michael/Maple Lawn Cemetery
Rawson Park
Clinton Ct
Washington St
W Main Cross St
E Main Cross St
Blanchard River
Findlay Country Club
Bright Rd
Heatherwood Dr
OH-568
Township Road 208
Township Road 207
Blanchard River
W Main Cross St 12
Putnam St
W Sandusky St
E Sandusky St
I-75 S
OH-15 E
OH-15 W
US-68 N
W Lima St
Liberty St
S West St
S Cory St
S Main St
Beech Ave
Maple Ave
Park St
Eagle Creek
Fishlock Ave
2nd St
3rd St
6th St
Blanchard Ave
CR-180
Summit St
Hurd Ave
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Lake Cascades Pky
Byal Ave
Findlay Reservoir

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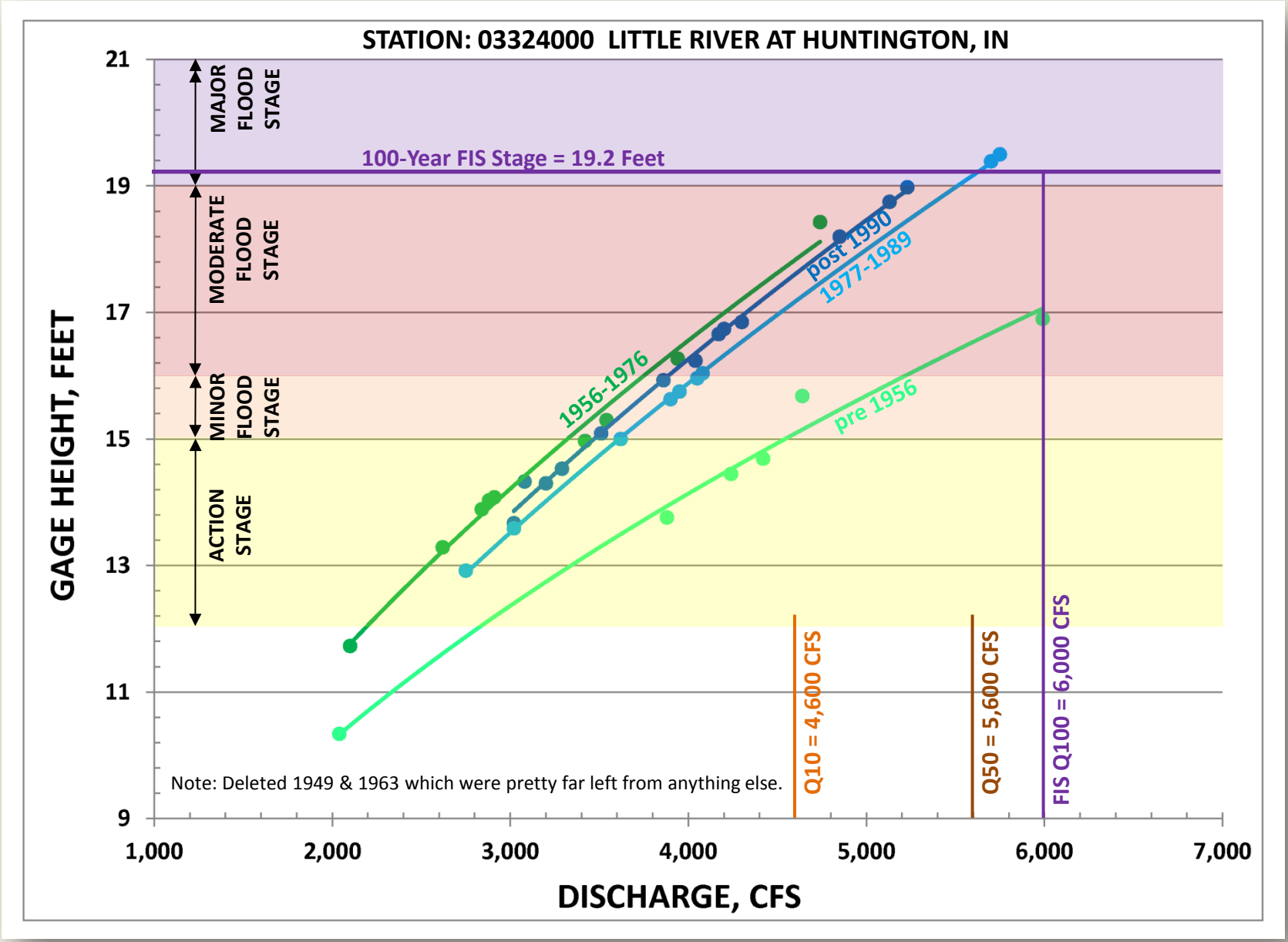
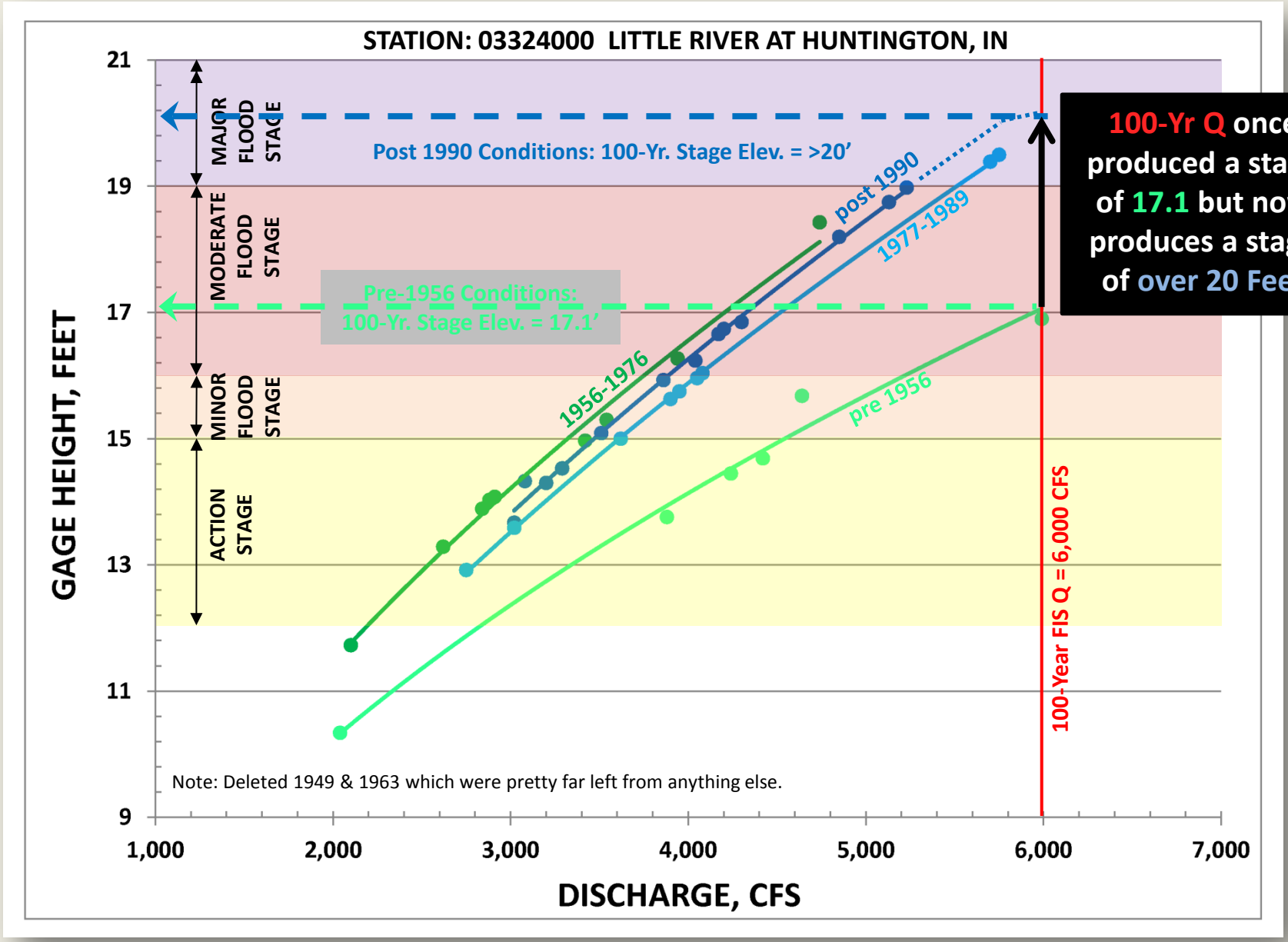
- What's happening with these factors?
- **What are the implications?**

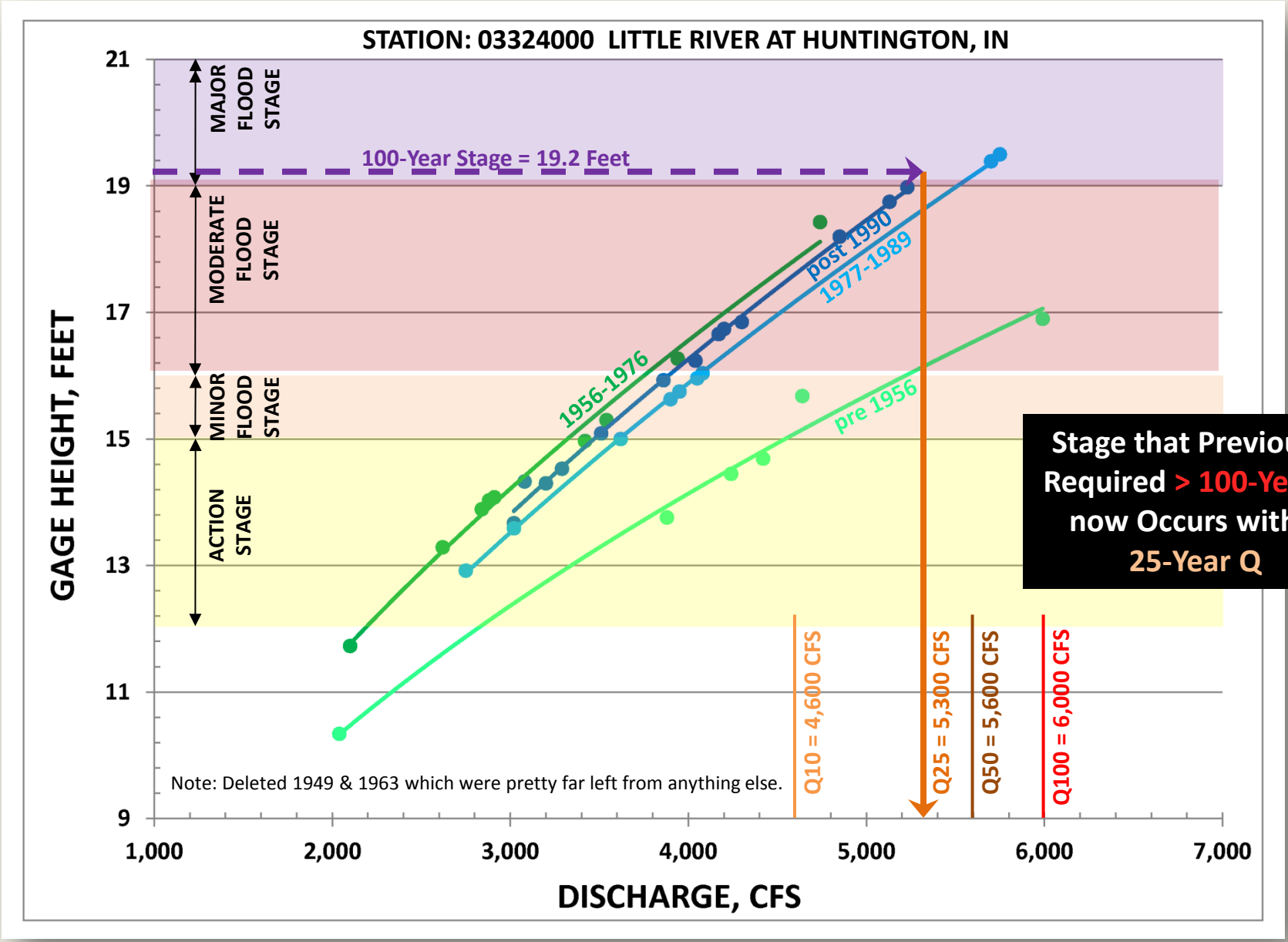
Implications



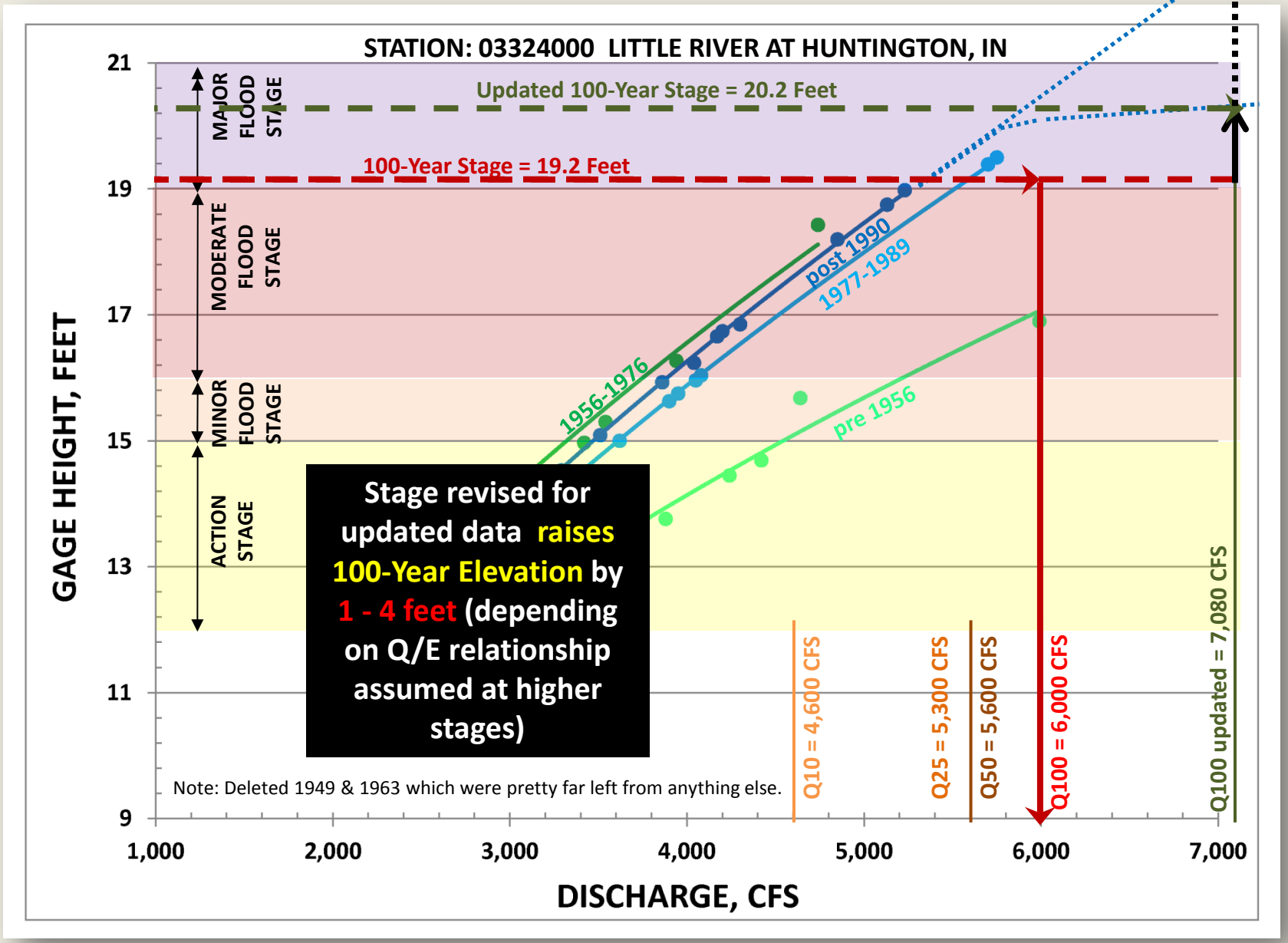
Change in Elevation Produced by 100-Year Discharge of 6,000 CFS



How has Discharge Frequency for FIS 100-Year Stage Changed?



Current BFE for FIS 100-Year Discharge



So…. What's Happening to the Factors That Go Into Making a Flood?

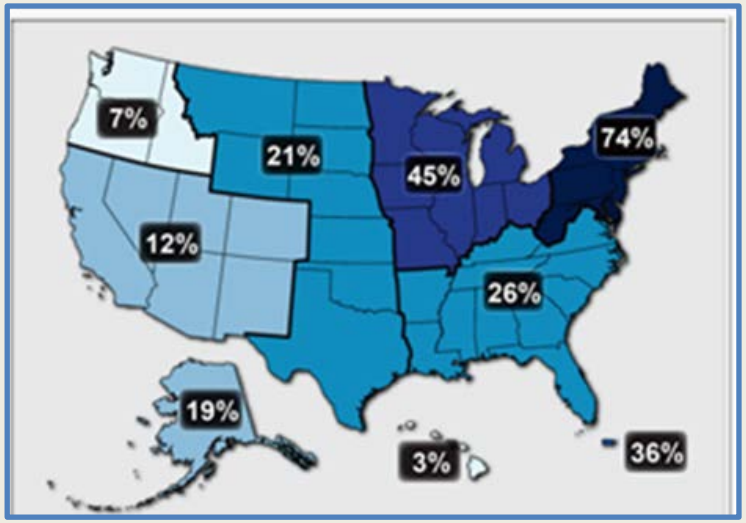
1) RAINFALL
   - Heavy rainfall amounts appear to be increasing
2) LAND USE
   - Detention regulations are generally controlling peak discharges at the regulated frequencies
   - More frequent discharges and runoff volumes that are not regulated are increasing with development
3) FLOW PATH
   - Regulation of only the conventional floodway does not necessarily prevent increased flood stages due to development along river corridors
   - Human activities, including flood fringe filling, levee construction, restrictive crossings, floodway encroachments, and intentional/unintentional channel modifications (increased erosion and sedimentation leading to stream bed aggradation), seem to be big contributors to increased flood stages
   - Many stream gages are showing increasing stages for the same discharge

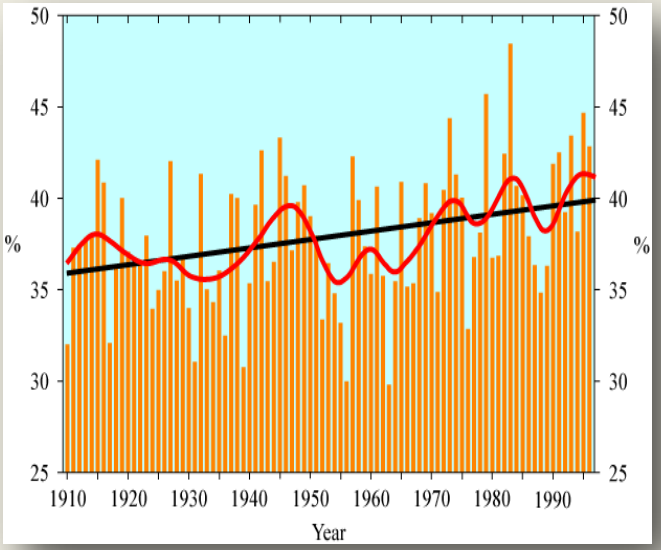
Is Flooding Getting Worse?

- What factors go into making a flood?
- What's happening with these factors?
- What are the implications?

Can We Do Anything?

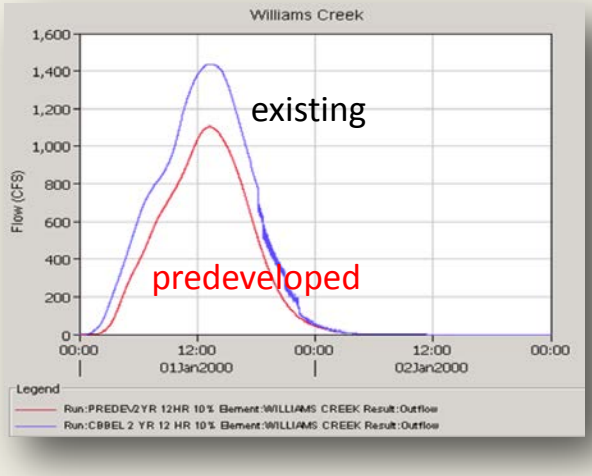
1) Meeting the Challenge of Higher Rainfalls

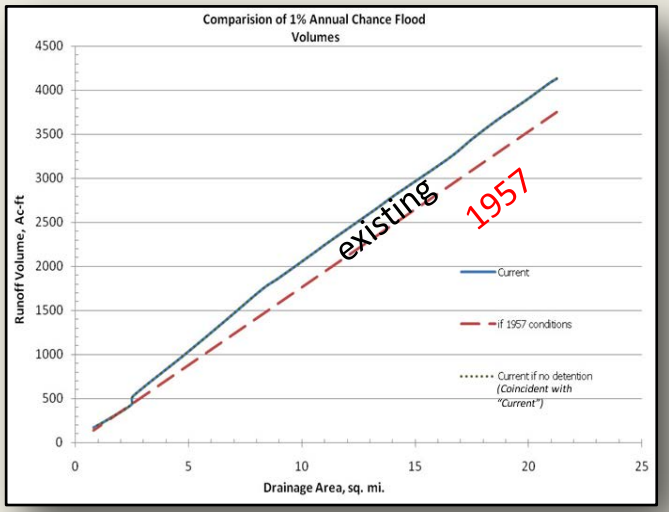




- Design for higher flood stages (consider future hydrology, higher freeboard, etc.)
- Identify potential risk areas (above and beyond minimum NFIP criteria) and stay away from them!
- Retrofit/floodproof critical facilities with a higher freeboard

2) Meeting the Challenge of Land Use Changes





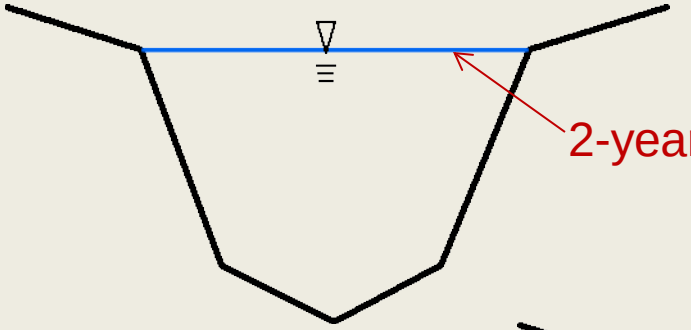
No-Adverse-Impact (NAI) Measures*

- Detention Ponds with accurate range of release rates to control peak discharges
- Retain/replace more pervious area to control runoff volumes
- Channel Protection Volume Retainage (through LID/Green) or extended detention to control volume

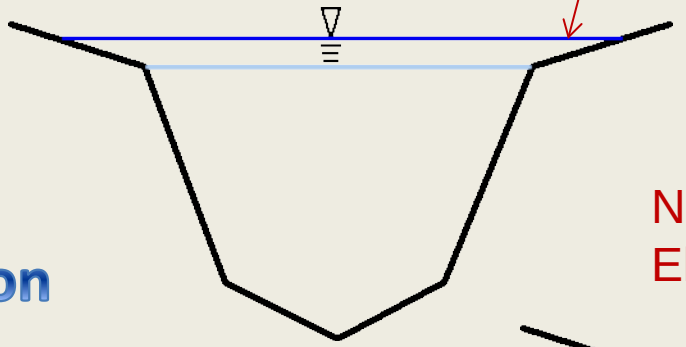
* NAI is an ASFPM initiative (**www.floods.org**)

Why Channel Protection Volume?

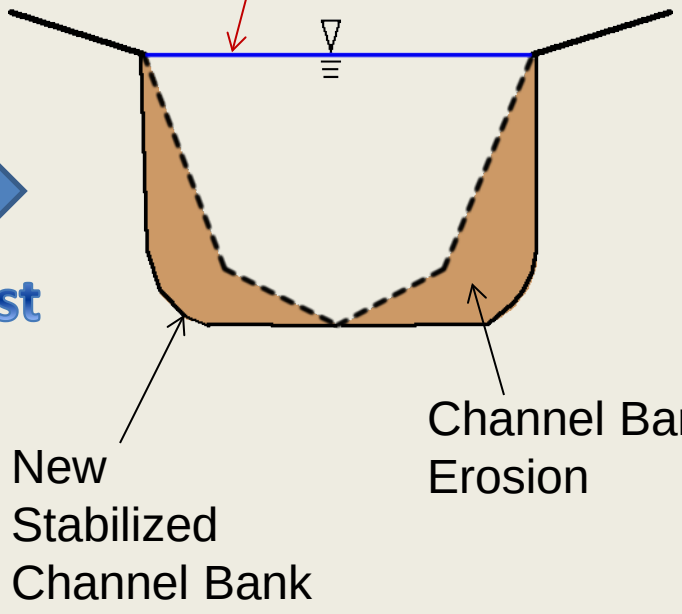
- Most jurisdictions control peak runoff from 2- to 100-year storm and some control the first inch of rainfall (first flush treatment for water quality)
- There is a “gap” in the current control mechanisms that, if not addressed, may lead to increased streambank erosion in receiving channels.
- This “gap” is caused by neglecting to control the increase of runoff as a result of development for smaller flows generally resulting from rainfalls ranging from 1 inch to 3 inches for a 24 hour period (2-year frequency event)
- The problem is that increased, sustained runoff for channel-forming events (1-yr to 2-yr events) resulting from new upstream development causes the channel to seek a new shape through eroding its banks



Urbanization



Time Past



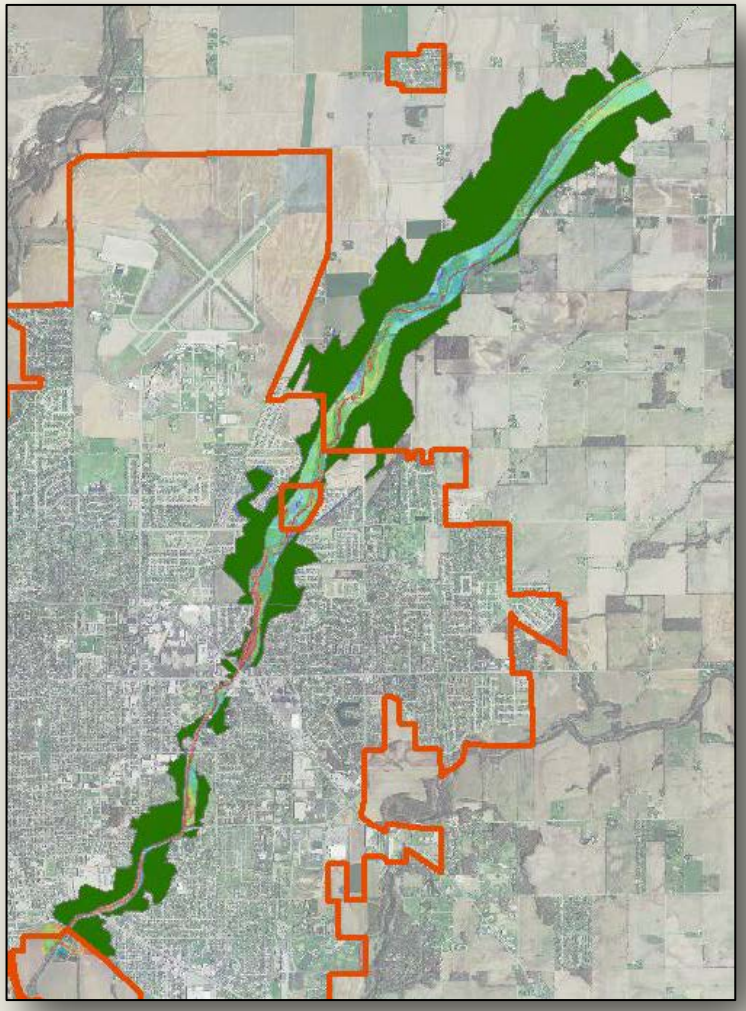
What is the Proposed Fix?

- The proposed fix is to retain (preferably) through various distributed storage/infiltration measures or, at a minimum, provide extended detention of the 1-year, 24-hour event (generated about 2.5 inches of rainfall) to prevent increased erosion in the receiving channel. This is known as "**Channel Protection Volume (CPv)**".
- The Channel Protection Volume can be addressed by:
  - conventional means (extended detention storage at the bottom of detention pond)
  - LID/Green Infrastructure (reducing impervious areas and providing distributed storage with infiltration/filteration capabilities)

3) Meeting the Challenge of Impacts on the Flow Path

No-Adverse-Impact Measures:

- Identify and protect/replace overflow paths for higher floods
- Avoid Floodplain areas or ,at a minimum, Require compensatory floodplain storage
- Accurately determine flood risk areas
- Some situations warrant unsteady state or 2D modeling of stream corridor (incl. auxiliary flow paths)
- Evaluate encroachment impacts for range of flows (2-year thru 500-year or flood of record, if larger)
- Don’t allow encroachments if adverse impacts are expected!



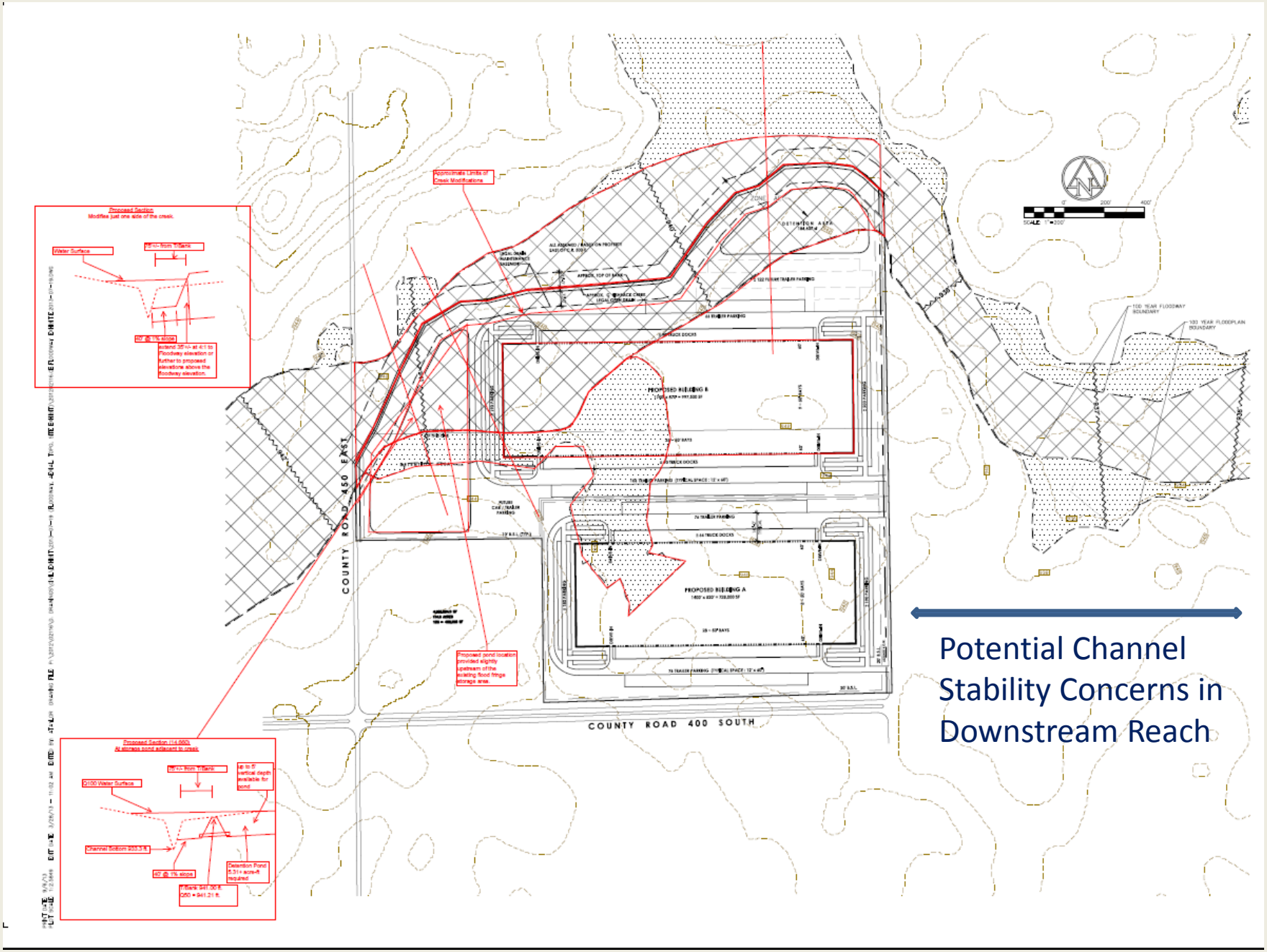
Meeting the Challenge of Higher Flood Stages (and Increased Erosion) for the Same Discharge

- Strictly Enforce regulations designed to prevent increased flood stages
- Select freeboards sufficient to provide protection from increasing stages
- Control Erosion and Sedimentation to decrease streambed aggradation (2-stage ditch, cover crops, infiltrate/retain CPv)
- Be mindful of inadvertent stream channel de-stabilization caused by piecemeal channel modification projects
- Remove/retrofit or **don't allow encroachments within Floodway** if adverse impacts are expected!

Why Avoiding Impacts to Floodway?

- Floodway is a unique zone that accommodates both conveyance and floodplain storage
- Compensating for Floodway loss is very difficult and difficult to mimic (more conveyance at the price of less storage is not necessarily good!)
- 2-Stage Ditch projects, while beneficial to conveyance, may inadvertently de-stabilize channel morphology downstream and does not address the loss of floodplain storage function
- In order to minimize disturbance to other reaches, 2-stage ditch projects must be correctly sized and must extend downstream for an adequate distance until stable channel reaches are reached
- Recent Fluvial Erosion Hazards (FEH) work in Indiana has shown that the FEH corridors are pretty close to floodway limits. Therefore, avoiding disturbance to floodway will also minimize channel erosion impacts

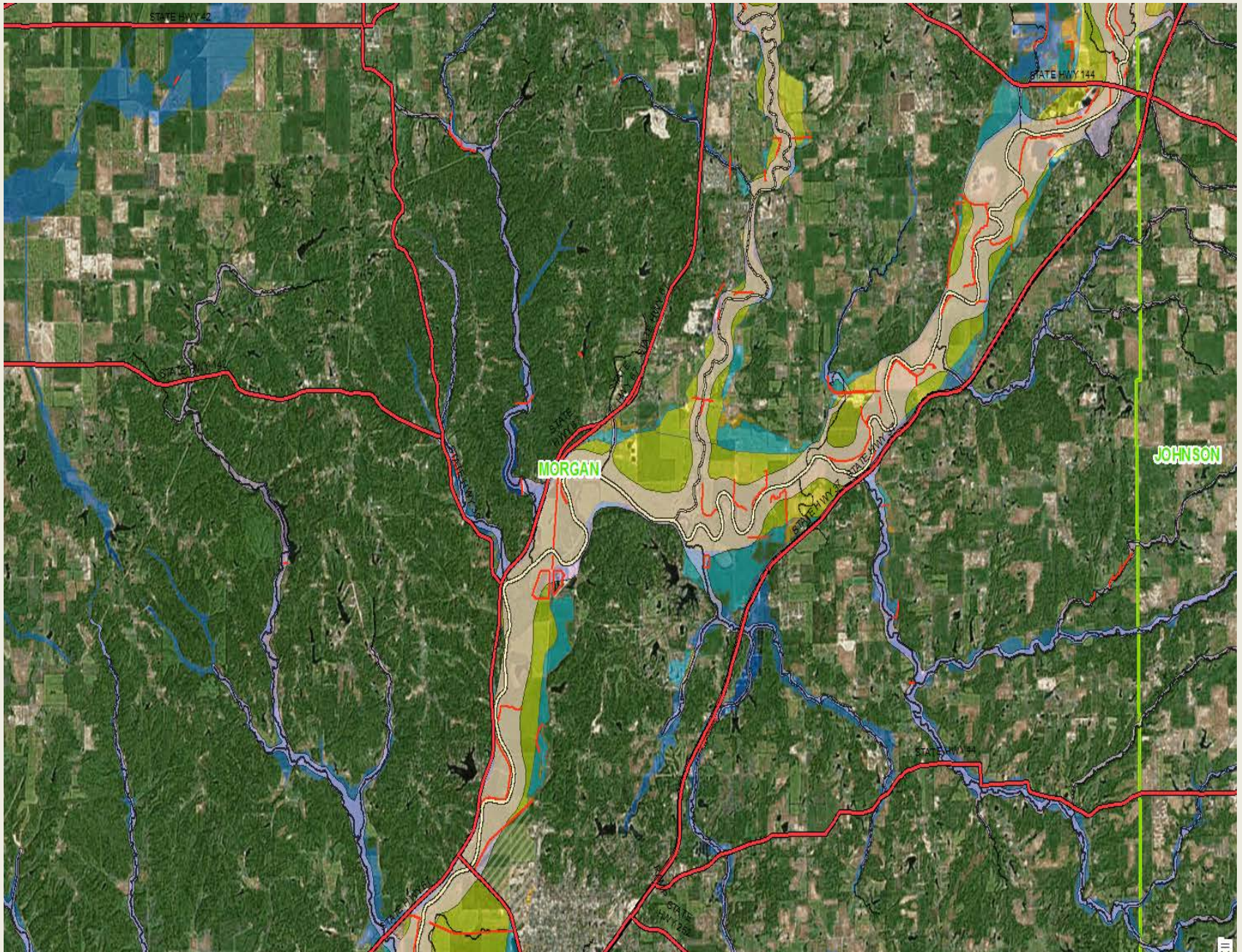
Compensatory Storage/Conveyance may NOT be Adequate!



Indiana FEH Regional Map (hachured) with floodway (yellow), and 1-percent annual chance flood zone (blue) for Plainfield, Indiana

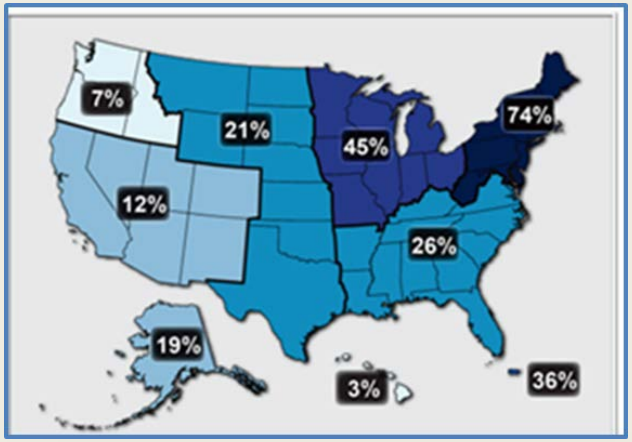
M. Riggs, Polis

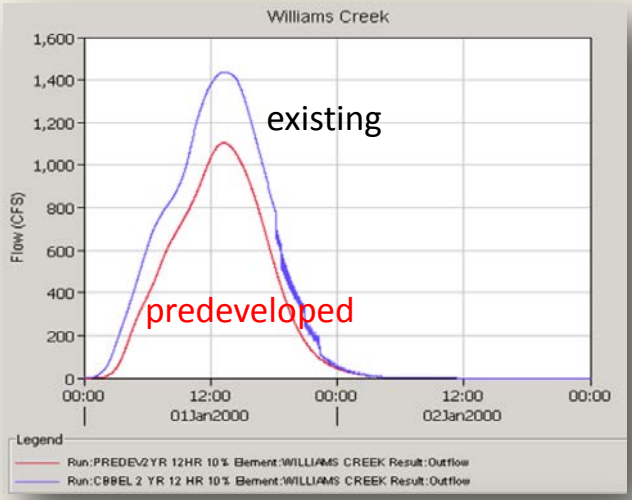
Indiana Regional FEH mapping, with floodway and the 1% annual chance floodplain for a portion of Morgan County, Indiana

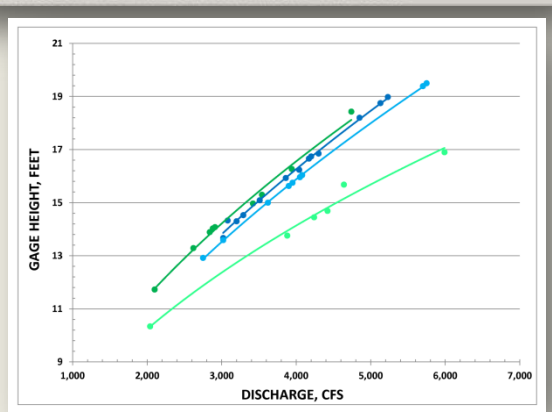


Conclusions

- Evidence shows **More Frequent, Higher Stages** in our streams due to multiple factors
- Contributing factors include **higher rainfalls, land use changes, and flow path modifications**
- Just complying with **Minimum Federal and State Regulations Have Not AND Will Not protect against increased flood stages and Erosion**
- You can do something about it by implementing **No-Adverse-Impact Measures**
- **Prohibit development in floodplain Areas and encroachment into floodway!**
- **Local Governments** (County, City, and Town levels) should initiate and require NAI measures appropriate for local conditions – **Upgrade your Stormwater Technical Standards!**
- **More research is needed** into gaged stream reaches and watersheds to understand reasons for the observed trends at the gage site and beyond
- **USGS gages** with long-term record are invaluable for understanding of flow and stage increase trends







Questions?

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